EAGLE POWER HANDBOOK

F-15/F100 Maintenance Awareness Program

PREFACE

The Eagle Power Handbook is published to provide maintenance personnel and others with information on the F100 engine, its operation and F-15 airframe interfaces. It is designed to complement, not replace, technical manuals.

This book is presented by the Maintenance Awareness Program which originated in 1981 to assist maintenance crews working on F100 engines. The program offers (1) a briefing on basic engine information and recent discoveries on how to best maintain the engine, (2) and this book, which expands upon the briefing's material for future reference.

An understanding of how the F100 is designed and how it operates is a prerequisite for anyone maintaining the engine. We hope this book will fulfill that requirement. We encourage you to participate in the Maintenance Awareness Program by attending the briefing and by becoming familiar with the information contained in this book.

The Eagle Power Handbook is divided into nine sections. A table of contents is given on page iii and a list of illustrations on page vi for easy reference. All acronyms used in text are defined on page 115.

If the program can help you in any other way, don't hesitate to contact your local Pratt & Whitney field service or logistics representative, or directly contact the Maintenance Awareness Program by writing to: Maintenance Awareness Program (M/S 723-03), Pratt & Whitney, P.O. Box 2691, West Palm Beach, FL 33402.

The information in this book is prepared to improve your knowledge of the F100 engine and F-15 airframe interfaces only. The data contained herein shall not be considered in any way as replacing or superseding information contained in F100 engine technical orders, F-15 aircraft technical orders or other official publications. Copyright United Technologies Corporation, 1984.

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ENGINE DESCRIPTION

The F100 is a low-bypass, high-pressure ratio, dual-spool, afterburning turbofan engine (Figure I-1). It has a 13-stage axial compressor, an annular combustor and four-stage turbine. The F100 is also equipped with a full-length annular fan duct, a mixed-flow afterburner and a variable convergent/divergent balanced beam exhaust nozzle.

The engine is approximately 191.5 inches long, has a maximum diameter of 46.6 inches, an inlet flow diameter of 34.8 inches and an approximate dry weight of 3,033 pounds.

The F100's major design features, which are described on the following pages, are:

- High-pressure-ratio design
- Modular construction
- Primary control system.

The F100 is built with a:

- Fan rotor assembly (three-stage fan rotor, two-stage turbine, three bearings)
- Rear compressor assembly (10-stage compressor rotor, two-stage turbine with air-cooled blades and vanes, two bearings)
- Variable vanes (fan inlet guide vanes, rear compressor inlet guide vanes, rear compressor fourth and fifth stages)
- Combustor (annular, 16 fuel nozzles)
- Augmentor (mixed flow, five segments, electronic ignition, variable convergent/divergent balanced beam exhaust nozzle)
- Engine-mounted gearbox.

See Figures I-2 and I-3 for detailed views of the engine's construction.

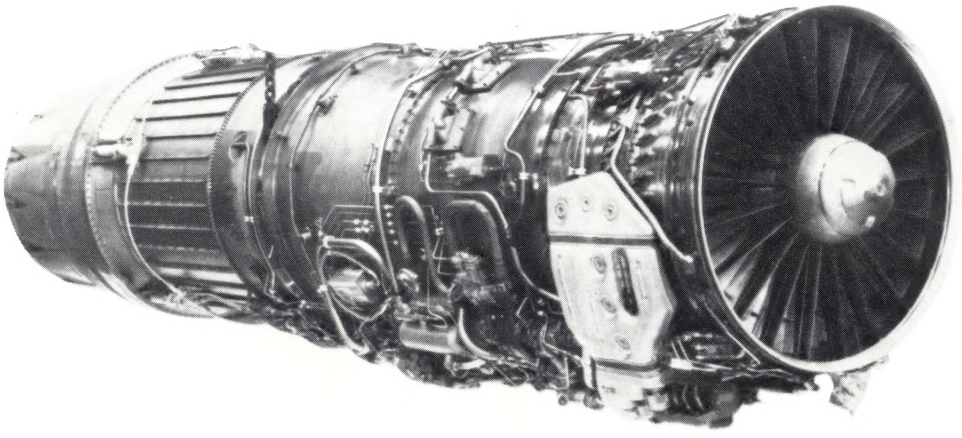


Figure I-1. F100-PW-100 Turbofan

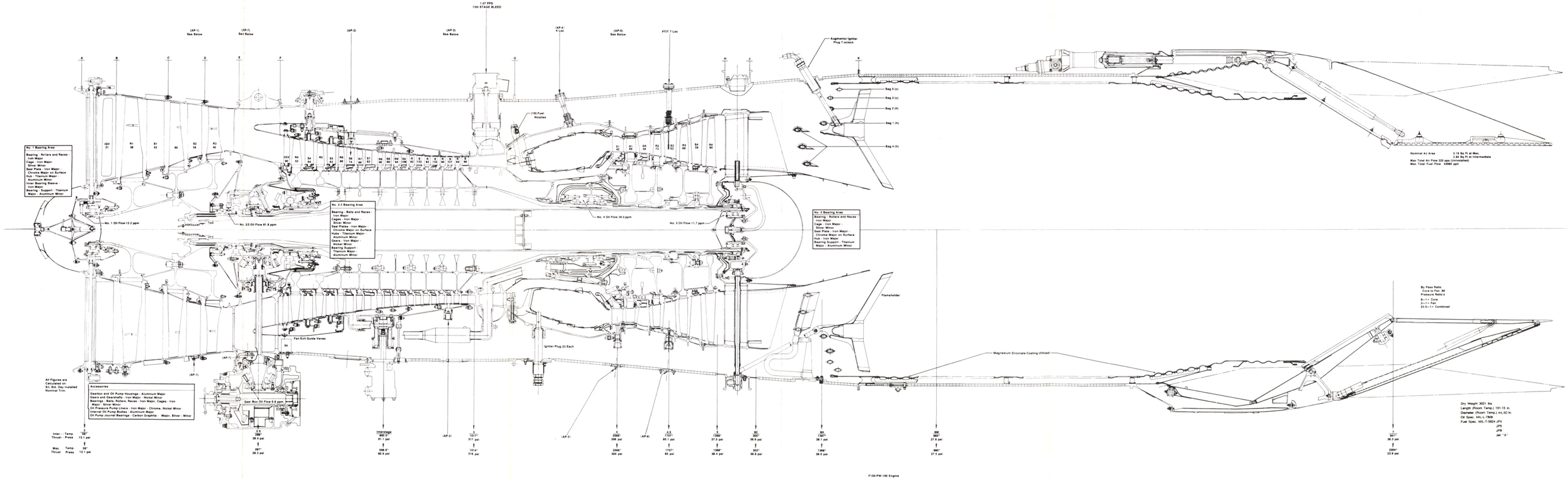
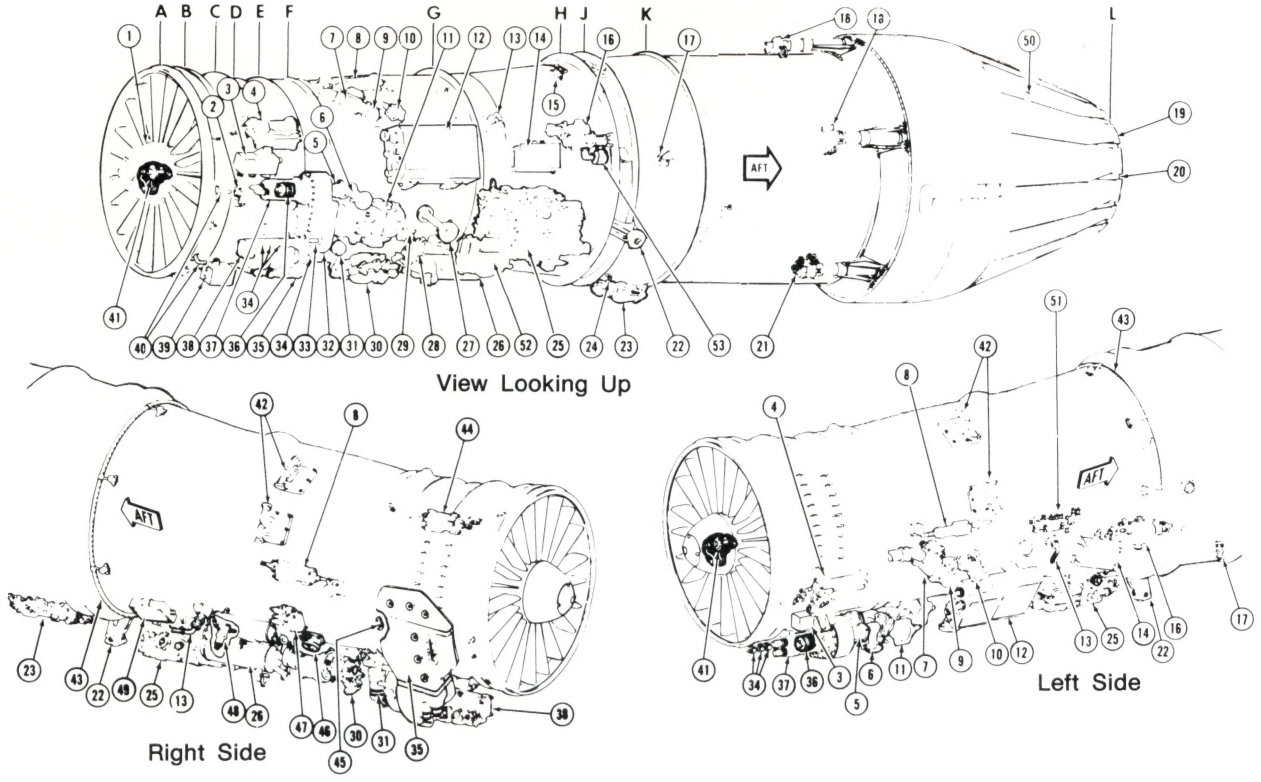


Figure I-2. F100 Cross Section

Engine Description

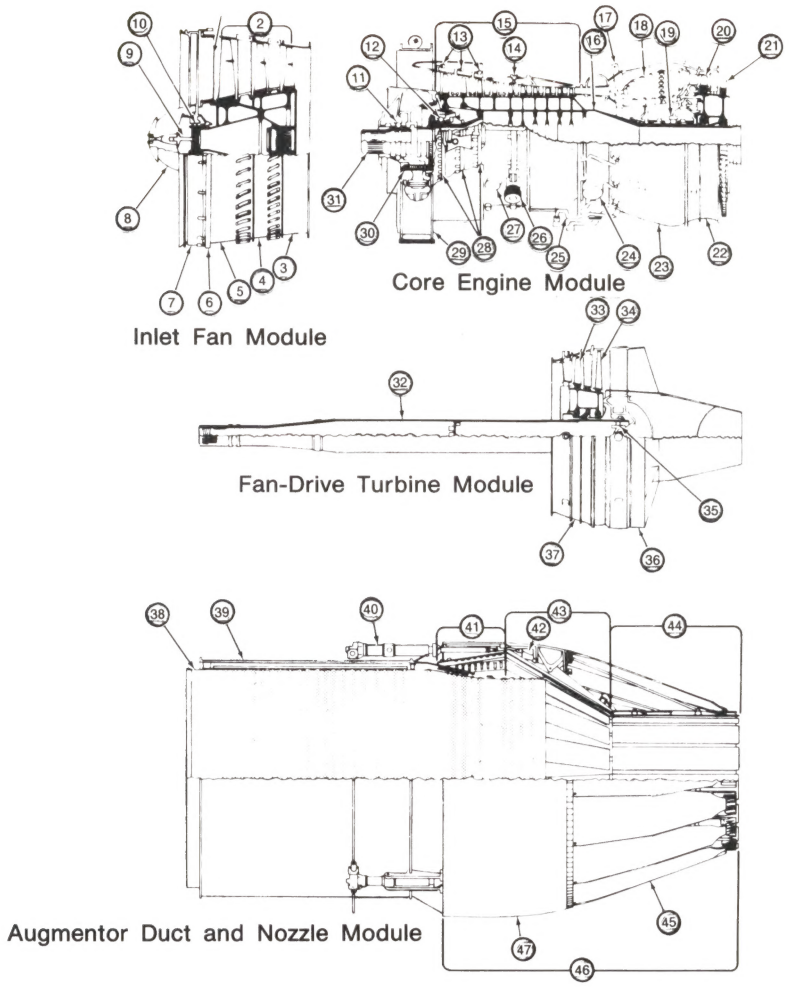
Section I



A-B Fan Inlet Case
B-C First-Stage Fan Case
C-D Second-Stage Fan Case
D-E Third-Stage Fan Case
E-F Compressor Intermediate Case
F-G Front Outer Fan Duct
K-L Augmentor Duct and Nozzle
G-K Rear Outer Fan Duct
H-J Thrust Frame

1. Compressor Inlet Cone
2. N_1 Sensor (External)
3. Engine Interconnecting Box
4. Compressor Inlet Variable Vane Control and Cylinder
5. Breather Pressurizing Valve
6. Breather Pressurizing Valve Housing
7. Anti-Icing Valve
8. Rear Compressor Variable Vane Actuator
9. Anti-icing Manifold Connector Tube and Transfer Tube
10. Compressor Bleed Cylinder
11. Main Fuel Pump
12. Engine Electronic Control
13. Main Igniter
14. Dual (Left) Ignition Exciter
15. FTIT Sensor
16. Convergent Exhaust Nozzle Control Air Regulator
17. Augmentor Igniter
18. Secondary Convergent Nozzle Actuator
19. Augmentor Divergent Nozzle Segment
20. Augmentor Divergent Nozzle Seal
21. Primary Convergent Nozzle Actuator
22. Rear Fuel Drain Manifold Connector
23. Convergent Exhaust Nozzle Control
24. Average Pressure Probe (P_t6)
25. Unified Control
26. Fuel Oil Cooler
27. Front Fuel Drain Manifold Connector
28. Fuel Pressurizing and Dump Valve
29. N_2 Sensor
30. Augmentor Fuel Pump
31. Oil Filter and Cold Start Relief Valve
32. Gearbox
33. No. 2 and 3 Bearing Scavenge Pump
34. Chip Detectors
35. Oil Tank
36. Engine Alternator (Generator Rotor)
37. Engine Alternator (Generator Stator)
38. Oil Pump
39. Events History Recorder
40. T_t2 Sensor
41. Dual N_1 Sensor (Internal)
42. Air Oil Coolers
44. Compressor Inlet Variable Vane Actuator
45. Motional Pick-up Transducer
46. Fan Exit Temperature Sensor
47. Augmentor Fuel Pump Controller
48. Fuel Derichment Valve
49. Single (Right) Ignition Exciter

Figure I-3 (Part 1). F100 Component Locations



Inlet Fan Module

1. Compressor Inlet Variable Vane
2. Fan Stages, 1, 2 and 3
3. Third-Stage Fan Case
4. Second-Stage Fan Case
5. First-Stage Fan Case
6. CIVV Synchronizing Ring
7. Fan Inlet Case
8. Nose Cone
9. Dual N_1 Sensor
10. No. 1 Bearing

Core Engine Module

11. No. 2 Bearing
12. No. 3 Bearing
13. Rear Compressor Variable Vanes
14. Start Bleed Strap
15. Rear Compressor
16. Rear Compressor Drive Shaft
17. Fuel Nozzle
18. Combustion Chamber
19. No. 4 Bearing
20. First-Stage Turbine
21. Second-Stage Turbine
22. Front Turbine Case
23. Diffuser Case
24. 13th-Stage Bleed Port
25. Fuel Manifold
26. Bleed Strap Operating Mechanism
27. Seventh-Stage Bleed Port
28. RCVV Synchronizing Rings
29. Compressor Intermediate Case
30. Gearbox Drive Gear
31. No. 2 Bearing Coupling

Fan-Drive Turbine Module

32. Front Compressor Drive Shaft
33. Third-Stage Turbine
34. Fourth-Stage Turbine
35. No. 5 Bearing
36. Turbine Exhaust Case
37. Rear Turbine Case

Augmentor Duct and Nozzle Module

38. Augmentor Liner
39. Augmentor Duct
40. Convergent Nozzle Actuator
41. Balance Flaps and Seals
42. Convergent Nozzle Synchronizing Ring
43. Convergent Flaps and Seals
44. Divergent Flaps and Seals
45. External Flaps
46. Exhaust Nozzle
47. Exhaust Nozzle Support

Figure I-3 (Part 2). Internal Hardware Locations

There are seven primary engine stations. The major points of reference and components (Figure I-4) are:

Station	Components
2 (Engine Inlet)	Two T_{t2} Probes
2.5 (Rear Compressor Inlet)	Dual $T_t2.5$ Sensor
3 (Rear Compressor Exit)	P_b Probe
4.5 (Fan Turbine Inlet)	Seven Temperature Probes (FTIT)
6 (Augmentor Inlet)	Augmentor Signature Elimination Probe (P_{t6})
7 (Exhaust Nozzle Throat)	A_j (Convergent Nozzle Area)
8 (Exhaust Nozzle Exit)	A_e (Divergent Nozzle Area)

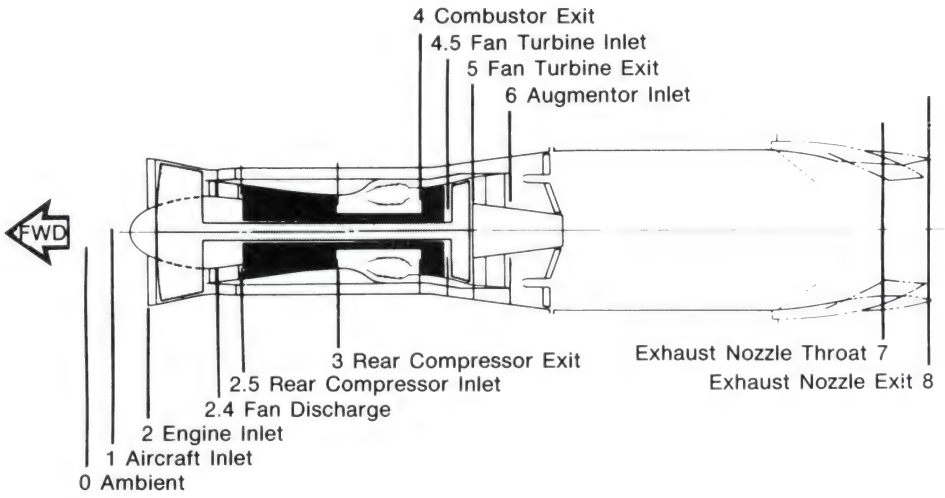


Figure I-4. F100 Engine Stations

HIGH-PRESSURE-RATIO DESIGN

The F100 gets its high performance from a three-stage fan which increases ambient air pressure threefold (Figure I-5).

About 40 percent of the air is discharged into the fan duct while the remaining 60 percent enters the engine core. The core consists of the compressor, the combustor and the compresssor-drive turbine. The 10-stage compressor further increases air pressure eight times. Thus the air being supplied to the core engine's annular combustor is 24 times higher in pressure than it was before entering the engine. The air is mixed with fuel in the combustor and ignited. The burning mixture then exits through the compressor-drive turbine and the fan-drive turbine where energy is extracted to drive the compressor and fan before entering the afterburner.

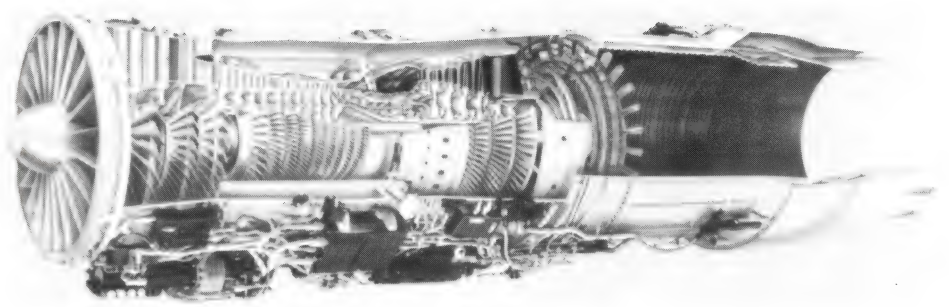


Figure I-5. High-Pressure-Ratio Design

The fan-discharge (bypass) air is mixed with the core engine exhaust gases in the afterburner. Since it hasn't been subjected to combustion like the air passing through the core, the fan-discharge air provides high-performance combustion in the five-zone afterburner to provide additional thrust.

MODULAR CONSTRUCTION

The F100 is a modular engine so that parts associated functionally or physically can be removed as units. The five modules are the inlet fan, core, fan-drive turbine, augmentor and exhaust nozzle, and gearbox (Figure I-6).

The modular design simplifies repair work at the JEIM level. For example, instead of sending a whole engine back to the depot for compressor FOD, only the core is sent while the undamaged modules remain in service. This means you have more modules and components at your base to meet mission requirements. Let's review each module's purpose, construction and additional data.

Inlet Fan Module

Purpose: Houses the three-stage, low-pressure fan.
Construction (Figure I-7):

- Inlet fan case (compressor inlet variable vanes and No. 1 bearing)
- First-, second-, and third-stage fan cases and rotors
- Fan-speed sensors.

Additional data:

- Fan blade replacement (moment weight — no rebalance, first- and second-stage removable from front without removing module)
- No. 1 bearing
- Borescope port AP1
- Mounts CIVV control
- Module identification plate
- Module weight, approximately 338 lb
- Length, 21 in.; diameter, 37 in.

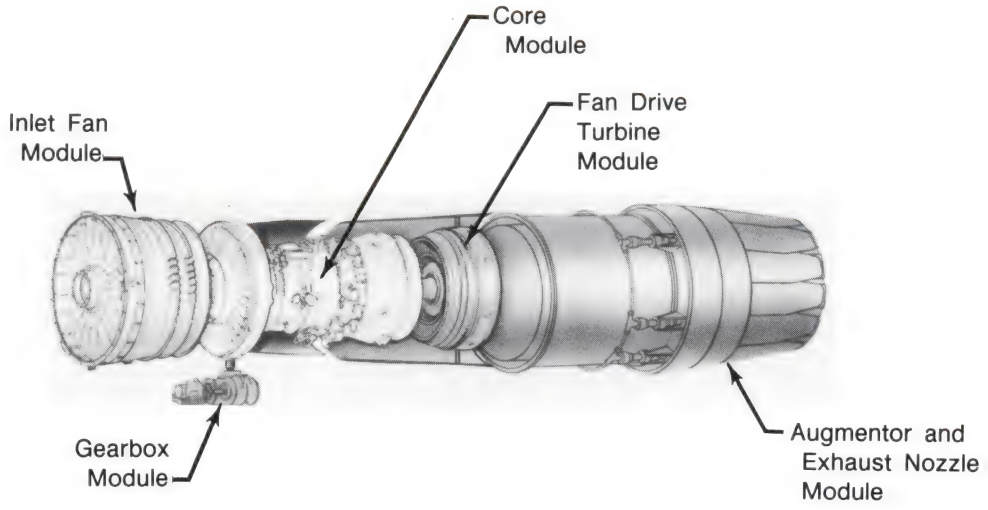


Figure I-6. F100 Modules

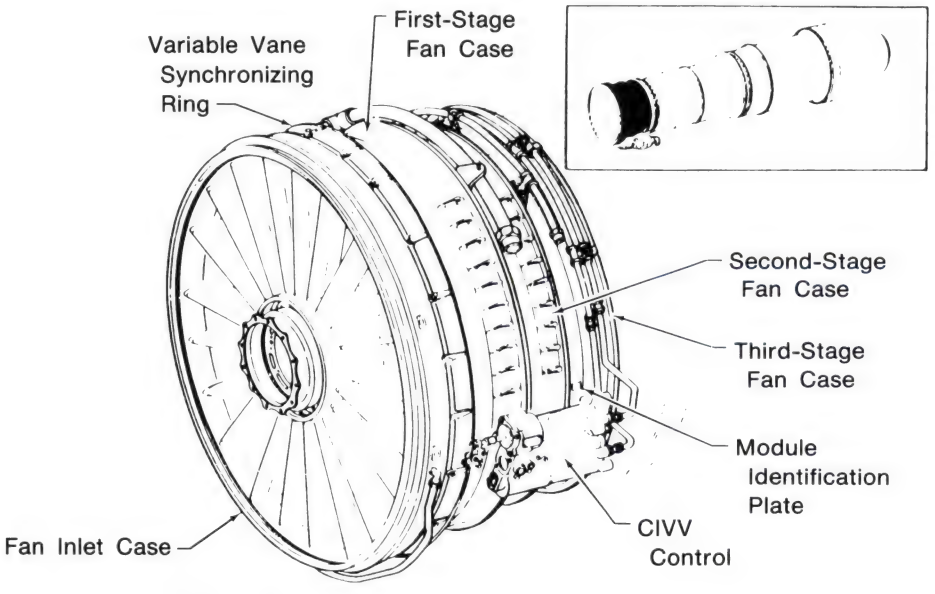


Figure I-7. Inlet Fan Module

Core Module

Purpose: Houses the rear-compressor rotor, combustor and rear compressor-drive turbine, and allows for complete replacement of the high-energy section of the engine.

Construction (Figure I-8):

- Intermediate case
- Rear compressor rotor and stator (10 stages)
- Rear compressor-drive turbine and stator assembly (two stages).

Additional data:

- Rear compressor variable vane system
- Start bleed strap
- 16 fuel nozzles
- Module weight, approximately 1,085 lb.
- Length, 59.4 in.; diameter, 33.6 in.
- Borescope ports
  - AP2 (sixth vane)
  - AP3 (12th vane)
  - AP4 (combustion chamber)
  - AP5 (first turbine NGV)
  - AP7 (intermediate case)
- No. 2, 3 and 4 bearings
- Bevel drive gears (gearbox drive).

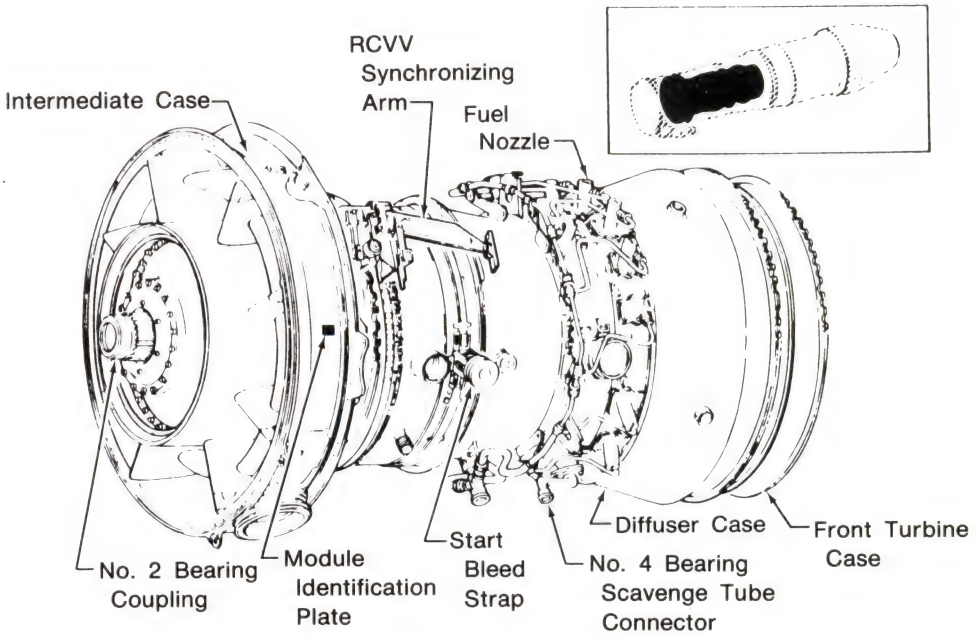


Figure I-8. Core Module

Fan-Drive Turbine Module

Purpose: Extracts energy from gases to drive the fan.

Construction (Figure I-9):

- Fan-drive turbine shaft
- Third- and fourth-stage turbine rotors and vanes
- Rear turbine case
- No. 5 bearing.

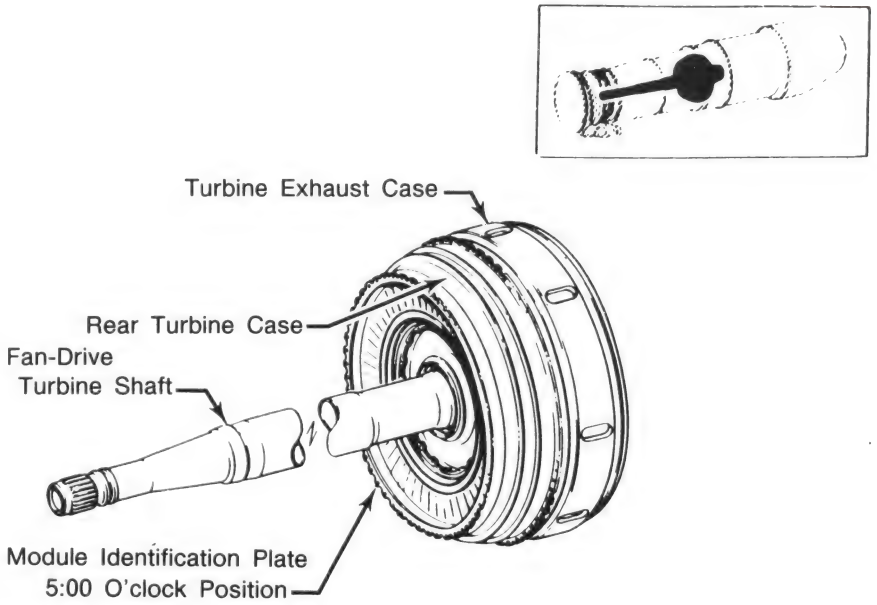


Figure I-9. Fan-Drive Turbine Module

Augmentor and Exhaust Nozzle Module

Additional data:

- Third- and fourth-stage rotor blades uncooled, shrouded tips
- Vanes made in pairs
- Seven third-stage vanes house FTIT probes
- Turbine exhaust case transmits No. 5 bearing loads through exit struts
- Four tension rods connect the No. 5 bearing support directly to aft fan duct
- Borescope port AP6
- Module weight, approximately 343 lb
- Length (with shaft), 72 in.; diameter, 30 in.

Augmentor

Purpose: Provides necessary duct for afterburner operation and variable nozzle to control N_1 (fan speed).

Construction (Figure I-10):

- Augmentor duct (cylindrical duct and combustion liner)
- Nozzle (convergent/divergent balanced beam).

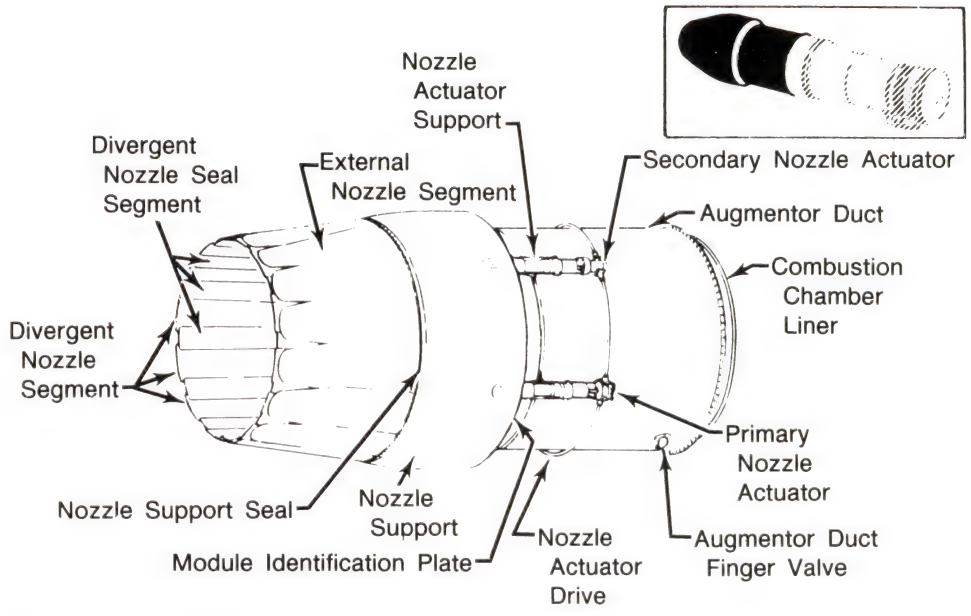


Figure I-10. Augmentor and Exhaust Nozzle Module

Additional data:

- Convergent nozzle (operated by master actuator and four slave actuators)
- Divergent nozzle (free floating)
- Module weight, approximately 453 lb
- Length, 91 in.; diameter, 47 in.

Augmentor spray manifolds

Purpose: Deliver fuel to afterburner combustion area for afterburner operation.

Construction (Figure I-11): Five segments (seven pressure-sensitive expandable fuel rings).

Additional data:

- Attached to rear fan duct
- Segments 1, 2 and 4 are in hot stream
- Segment 4 is a 3-ring design
- Segments 3 and 5 are in the cold (fan) stream
- Nozzle orifice area is variable due to the flexibility of the manifolds
- Fuel is supplied through external lines from the unified control.

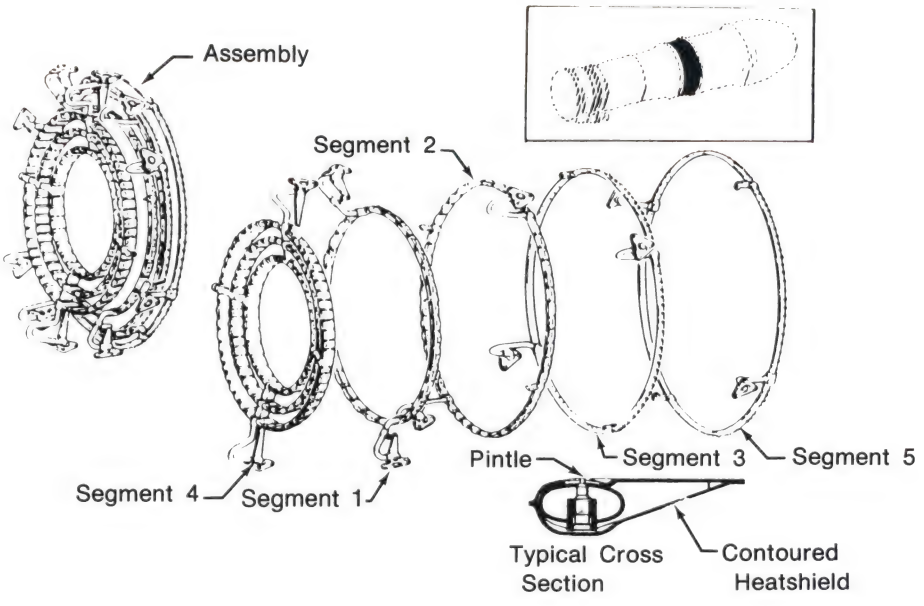


Figure I-11. Augmentor Spray Manifolds

Augmentor flameholder

Purpose: Controls flame propagation during afterburner operation and provides hot- and cold-stream mixing.

Construction (Figure I-12): Radial gutter type.

Additional Data:

- Attached to the rear fan duct
- Two types of flameholders: (1) original nonremovable flameholder requires removing the augmentor module for replacement; and (2) removable flameholder which can be replaced without removing the module (see TCTO 2J-F100-684 for proper procedures).

New engines are being delivered with the removable flameholder. Field retrofit will be by attrition.

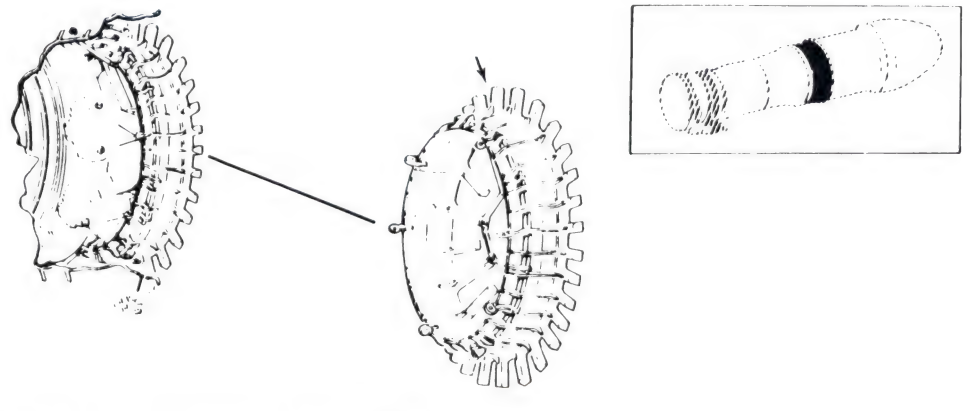


Figure I-12. Augmentor Flameholder

Gearbox Module

Purpose: Provides mounting pads and drives for main fuel pump, engine stator generator, PTO shaft and breather-pressurizing valve.

Construction (Figure I-13):

- Main gearbox
- Main oil pressure and scavenge pump assembly
- Main oil filter
- Four chip detectors
- Air oil separator.

Additional data:

- Attached to 6 o'clock position of intermediate case
- Module weight (dry), 78 lb
- Dimensions
  - — Length, 20 in.
  - — Width, 21 in.
  - — Height, 9 in.

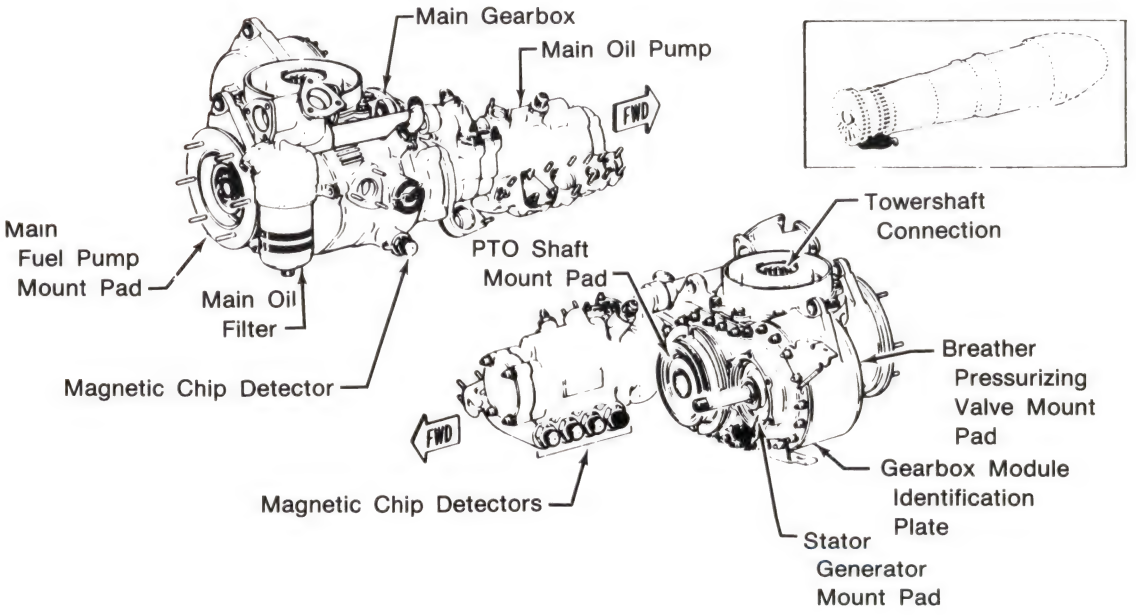


Figure I-13. Gearbox Module

Fan Ducts (Outer)

The fan ducts are not assigned to a module, but are serialized parts of the engine assembly.

Purpose: Form passageway for fan (bypass) airflow.

Construction (Figure I-14): Titanium honeycomb.

Additional Data:

- Provide numerous component attaching points
- Both ducts removable together with components attached
- No split line — full 360° duct
- Rear duct forms afterburner diffuser.

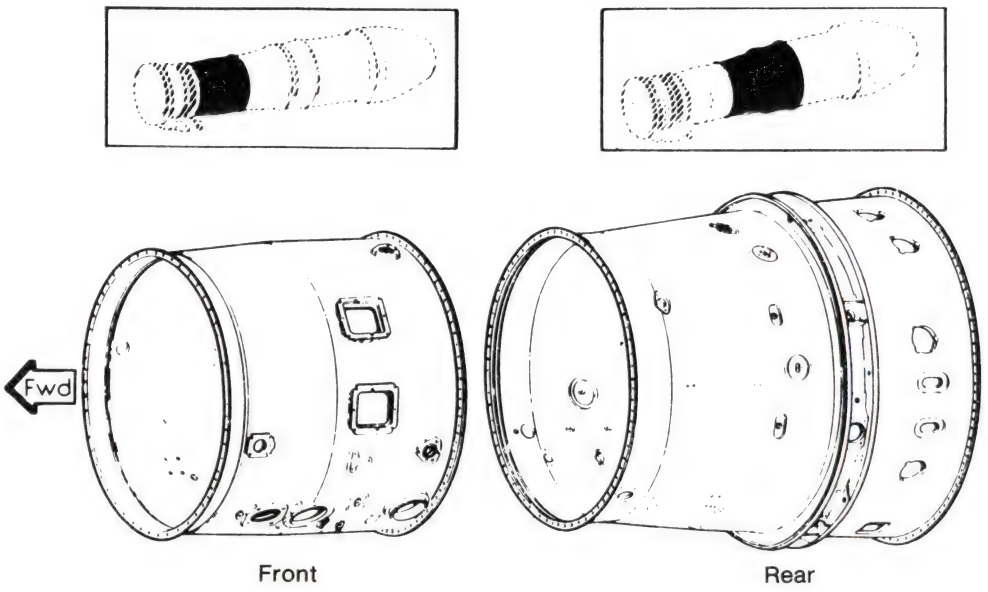


Figure I-14. Fan Ducts

PRIMARY CONTROL SYSTEM

Unified Control

The unified control, the heart of the engine hydromechanical control system, provides basic engine operation from cutoff to maximum afterburner.

The UC schedules RCVVs, nozzle position, start bleed position, core engine and afterburner fuel flow. It operates on inputs supplied by the N_2 (rpm) sensor, $T_t2.5$ sensor (fan-discharge temperature), P_b, EEC and other sensed parameters.

The engine electronic control fine-tunes the UC's basic operating schedules in many areas to optimize engine operation. It also provides the primary source of commands for CIVV scheduling, idle area reset, closed-loop idle, stall recovery logic, idle lockout at high Mach number, and Segment 5 A/B limiting. A schematic of the system is shown in Figure I-15.

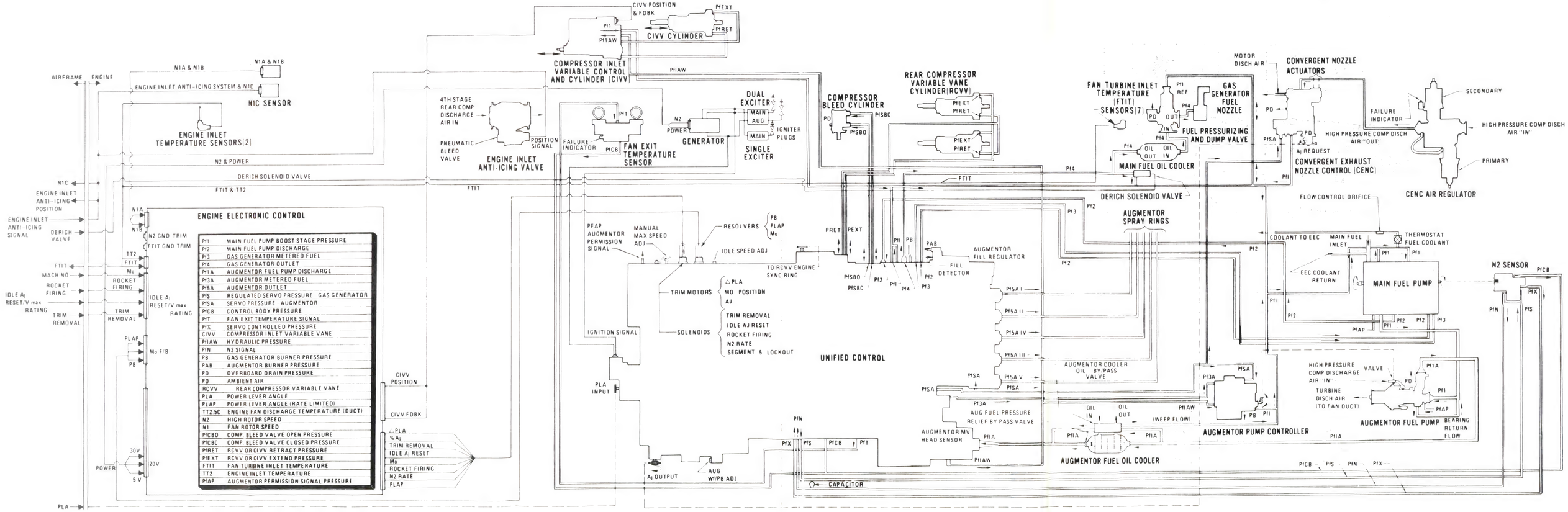


Figure I-15. F100 Control System

The following is a sequence of primary control system operation as shown in Figure I-16.

Start — UC schedules starting fuel flow and closes the start bleed.

Idle — UC provides a basic schedule for N_2 idle speed that is trimmed by the EEC to maintain a desired N_1. Idle can also be trimmed by the EEC to provide a minimum P_b.

Transient — UC schedules the acceleration and deceleration of gas generator fuel flow.

MIL power — UC provides a basic schedule for N_2 MIL power that is trimmed by the EEC to maintain desired FTIT (hot day) or N_2 (cold day). The UC also provides a basic schedule for A_j which is trimmed by the EEC to control airflow (N_1 rpm).

MAX power — UC provides A/B fuel flow sequencing and scheduling.

Ground Trims — UC idle, UC military, RCVVs, MAX Power fuel flow.

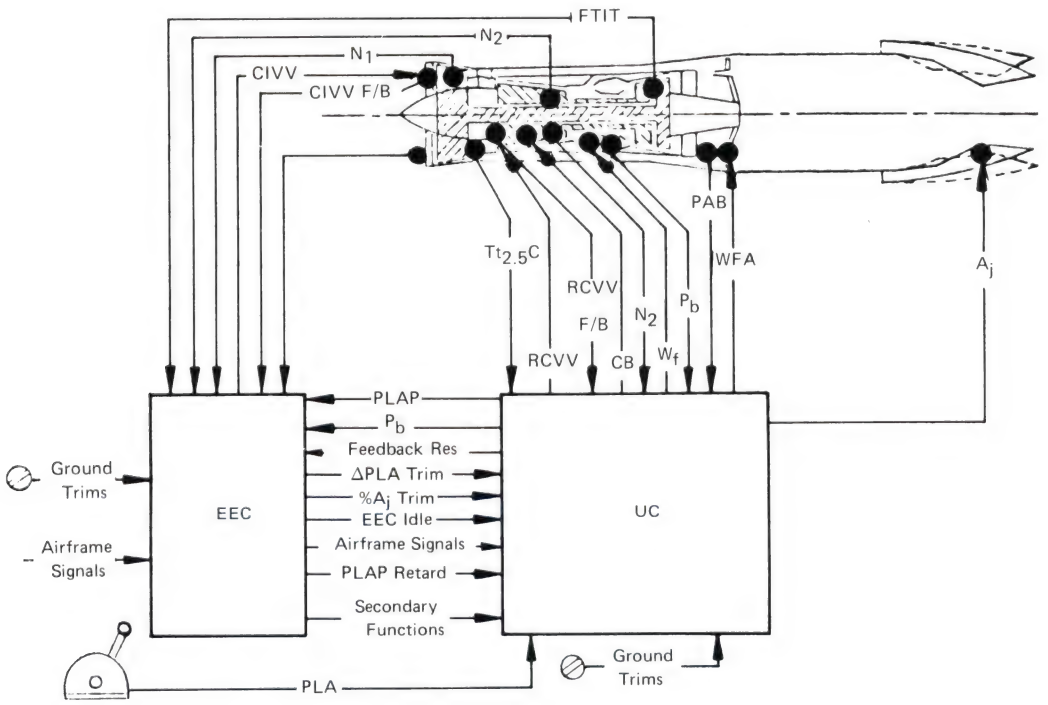


Figure I-16. Primary Control System Operation

Engine Electronic Control

The engine electronic control supervises the unified control.

EEC specifications

Type: Digital electronic computer.

Input signals (see Figure I-17):
- Engine (N_1, N_2, T_{t2}, FTIT, CIVV position)
- UC (PLAP, P_b, Max A_j, stepper motor positions)
- Airframe (Mn, V_{max}, trim removal)
- Ground trims (N_2, FTIT).

Output signals (see Figure I-17):
- Stepper motors (%A_j, PLAP, Mn position, CIVV position)
- Solenoids (trim removal, N_2 rate, idle area reset, PLAP retard, Segment 5 limiting).

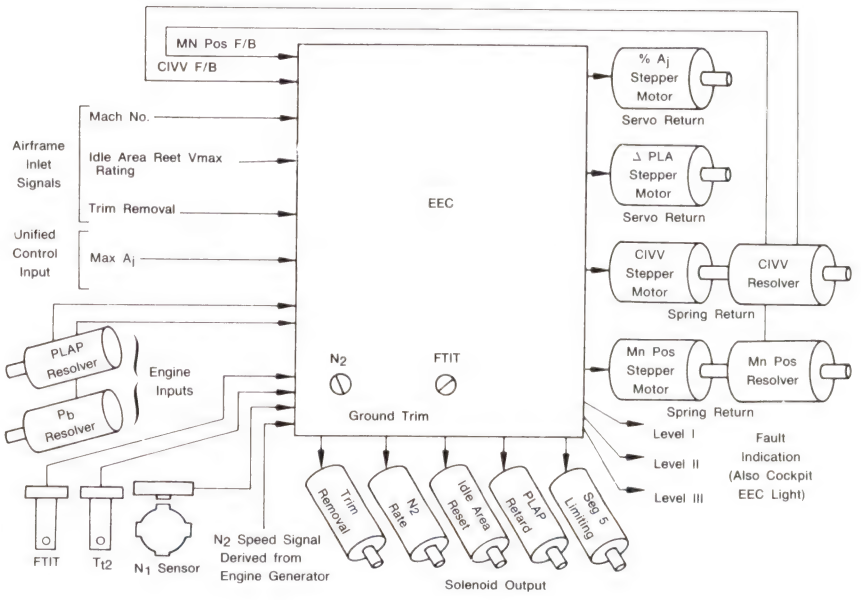


Figure I-17. EEC System Inputs and Outputs

ENGINE IGNITION SYSTEM

The ignition system (Figure I-18) provides constant ignition for gas generator operation and initial ignition for the A/B. The engine's self-contained system consists of two electrically independent circuits: one for right main ignition and one for left main and A/B ignition. The system consists of an engine-driven stator generator, one dual- and one single-output exciter, high tension leads and three igniters. A schematic of the engine electrical system is shown in Figure I-19.

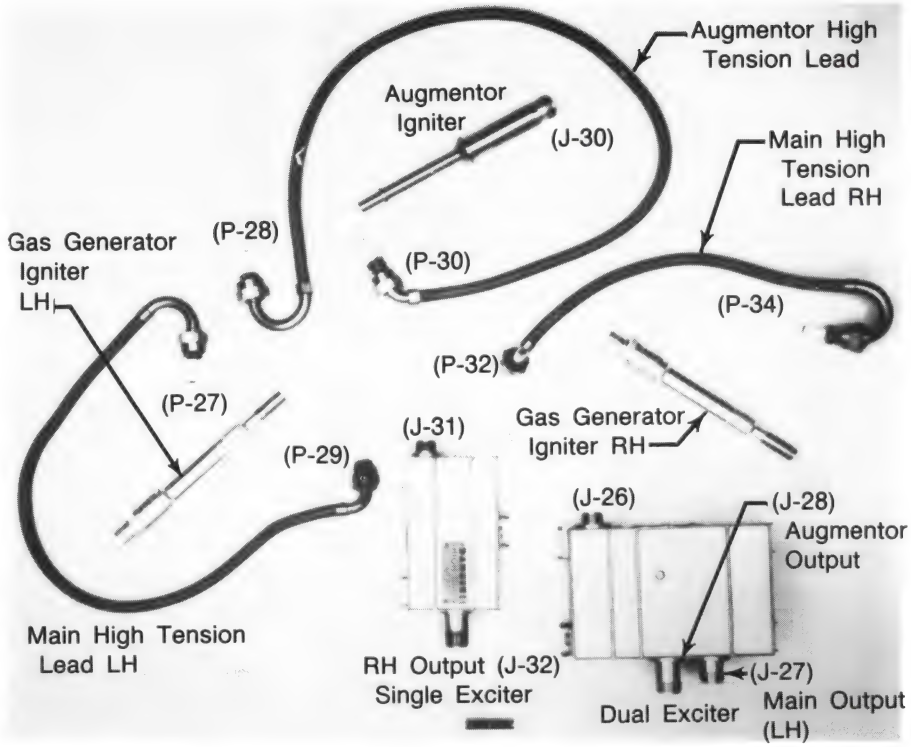


Figure I-18. Engine Ignition System

ENGINE INTERCONNECTING BOX

The interconnecting box (I/C box), Figure I-20, is mounted on the lower left side of the inlet fan module. It is the junction for electrical signals between various engine accessories and between the engine and airframe. P-numbered connectors on electrical cables are connected to corresponding J-numbered receptacles on the I/C box. Receptacles are also provided for airframe connectors and diagnostic equipment.

EVENTS HISTORY RECORDER

The events history recorder is an engine-mounted, fuel-cooled recorder that provides a direct readout of engine operating time, hot section operating time at two levels of FTIT, and LCF as a function of rear compressor operating speed (Figure I-21). In addition, the recorder provides warning indications for turbine overtemperature, hot start and fan rotor speed sensor failure. The EHR's 28-VDC power is provided by the airframe.

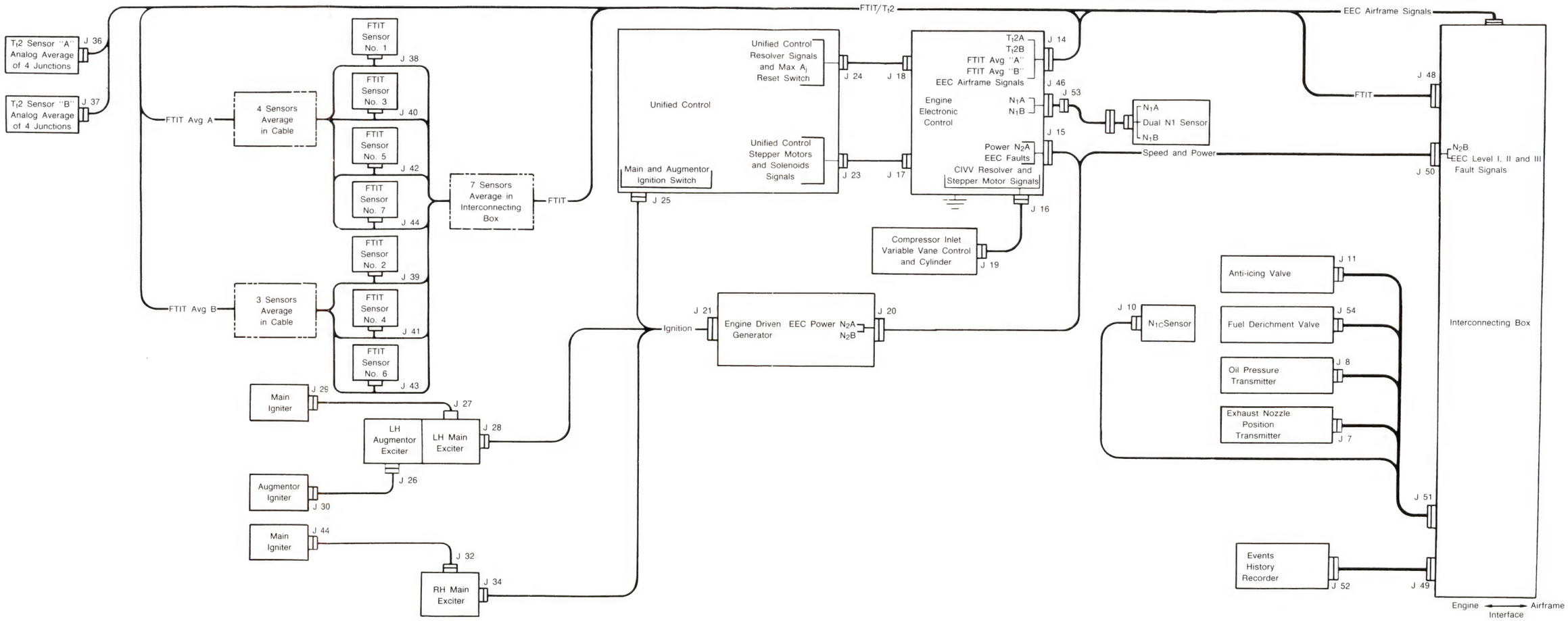


Figure I-19. Engine Electrical System Schematic

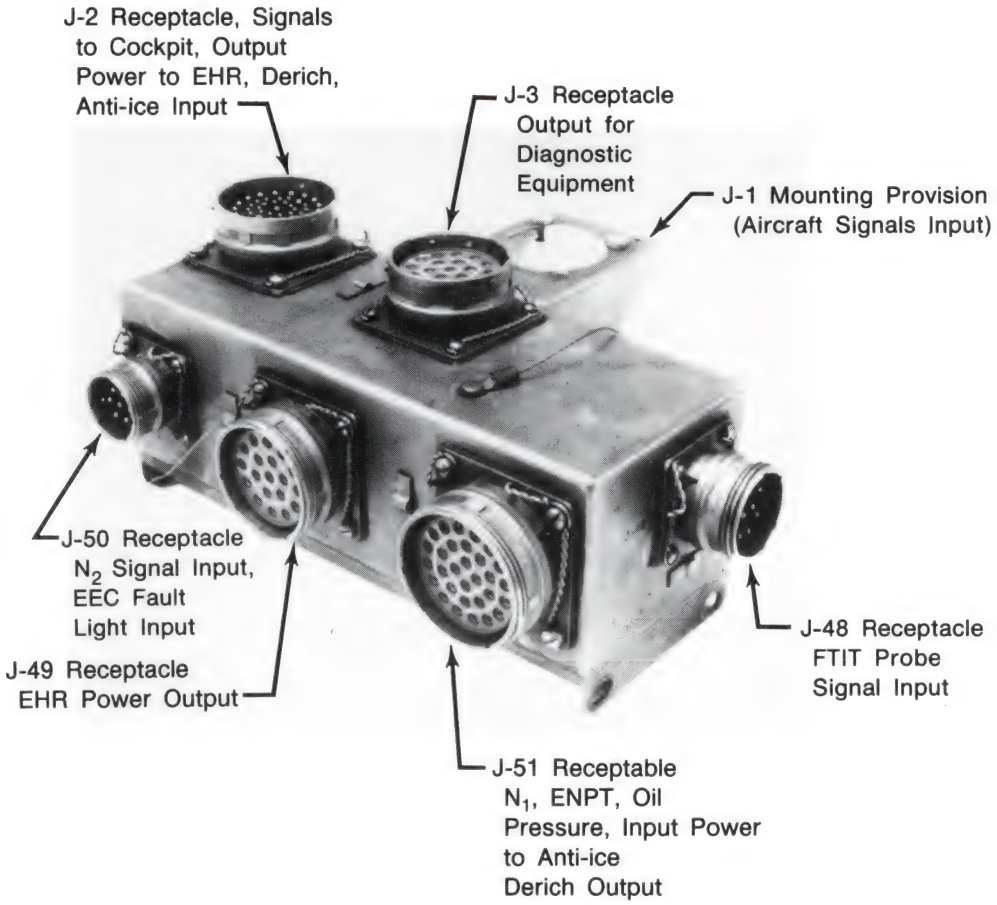

J-2 Receptacle, Signals to Cockpit, Output Power to EHR, Derich, Anti-ice Input
J-3 Receptacle Output for Diagnostic Equipment
J-1 Mounting Provision (Aircraft Signals Input)
J-50 Receptacle N_2 Signal Input, EEC Fault Light Input
J-49 Receptacle EHR Power Output
J-48 Receptacle FTIT Probe Signal Input
J-51 Receptable N_1, ENPT, Oil Pressure, Input Power to Anti-ice Derich Output

Figure I-20. Engine Interconnecting Box

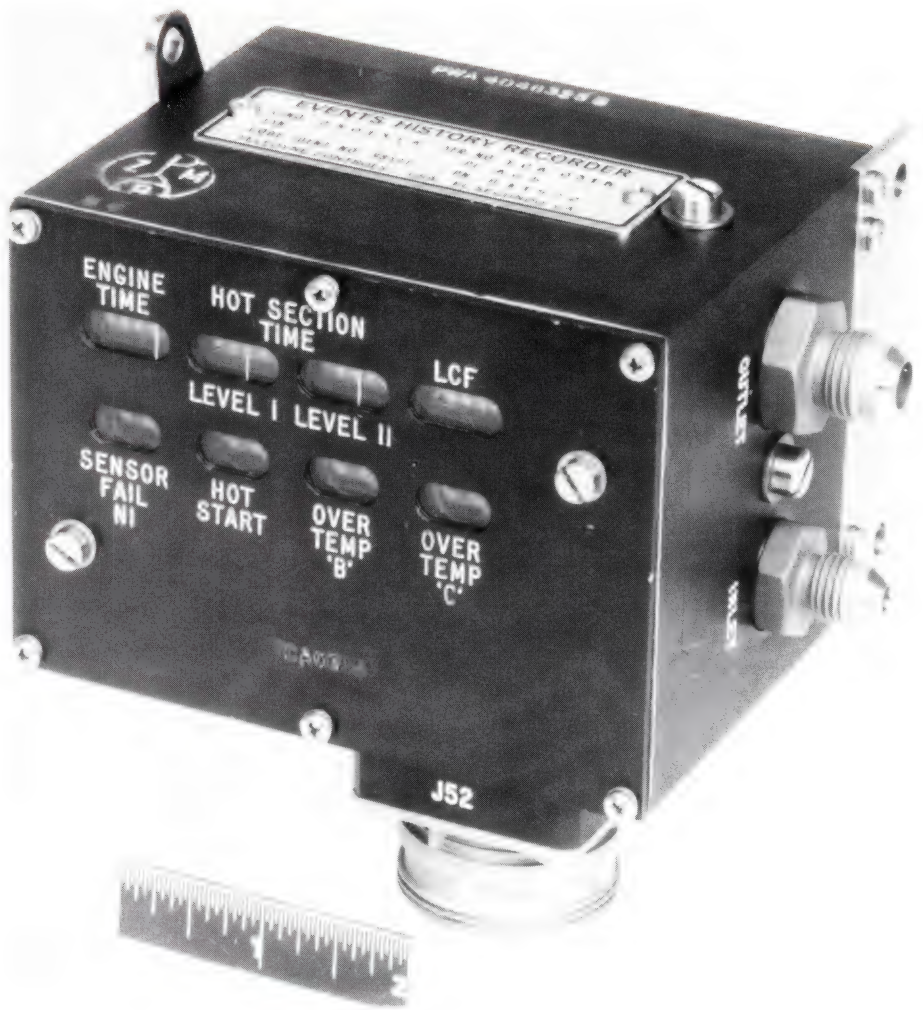


Figure I-21. Events History Recorder

The following describes how the EHR functions:*

Engine time — When the EHR supply voltage is above 17 VDC and FTIT is above 500°F (260°C), engine operating time is accumulated and is displayed on a digital indicator (0.1 hour minimum increment).

Hot-section time (Level I) — When FTIT is between 1692-1755°F (922-957°C), time is accumulated and displayed on a digital indicator (0.1 hour minimum increment).

Hot-section time (Level II) — When FTIT exceeds 1755°F (957°C), time is accumulated and displayed on a digital indicator (0.01 hour minimum increment).

Low-cycle fatigue — When rear compressor speed (N_2) increases from below 10,250 rpm to above 12,500 rpm (73-89%), one LCF count is accumulated on a digital indicator.

*Check T.O.s for changes to the given times and temperatures.

Overtemperature B — When FTIT exceeds 1868°F (1020°C) for a time equal to or greater than 3.0 seconds, the overtemperature B flag will indicate "fail."

Overtemperature C — When FTIT exceeds 1943°F (1061°C) for a time equal to or greater than 1.5 seconds, the overtemperature C flag will indicate "fail."

N_1 sensor failure — When FTIT is greater than 1548°F (842°C) and the EEC signals a Fault 1 (loss of one of the fan speed (N_1) signals), the N_1 sensor failure flag will indicate "fail."

Importance of Accurately Recording Data

It is important to be accurate when you record data from the EHR after each flight. The EHR not only clocks operating time of the engine, but tells you when the turbine's temperature is running too high.

The EHR also counts cycles, or how many times during operation the engine is cycled from a low-power setting to a high-power setting and back down again. We've learned over the years that cycles are a more reliable way of establishing operating (or life) limits on parts or components than total operating time.

So, take a few extra seconds to ensure the data you record is what the EHR displays. You wouldn't want to miss a popped flag or over-run cyclic limits on engine parts that can be "flown to failure" if you report erroneous information.

COMPONENT FAILURE DIAGNOSTIC PROVISION

There are several components that are designed to signal a failure. They are:

Dual N_1 sensor — A flag on the EHR means one side has failed. An EEC Fault III could mean a dual failure.

$T_t2.5$ sensor — A red flag means one side has failed (dual failure may not be recognizable by a flag).

Air regulator — The flag pops if the regulator is inoperative.

EEC fault indication —
Fault I: N_1 sensor failure (EHR Flag)

Fault II: Resolver feedback or Mach No. to EEC is out of limits (fault light)

Fault III: Critical parameter (N_2, FTIT, N_1) exceeds range check or EEC self-test indicates an internal failure (fault light).

FUEL FILTER ASSEMBLY

The fuel filter assembly traps foreign or domestic matter entrained in the fuel (Figure I-22). It is a last-chance filter prior to the fuel nozzles. A 400-micron cleanable/replaceable element, it traps particles larger than 0.016 inch (1 micron = .0000040 inch, or 40 millionths of an inch).

The fuel filter assembly is bolted to the P & D valve. At 3.6-5 psid the ΔP indicator pops; filter will bypass when ΔP reaches 15 psid.

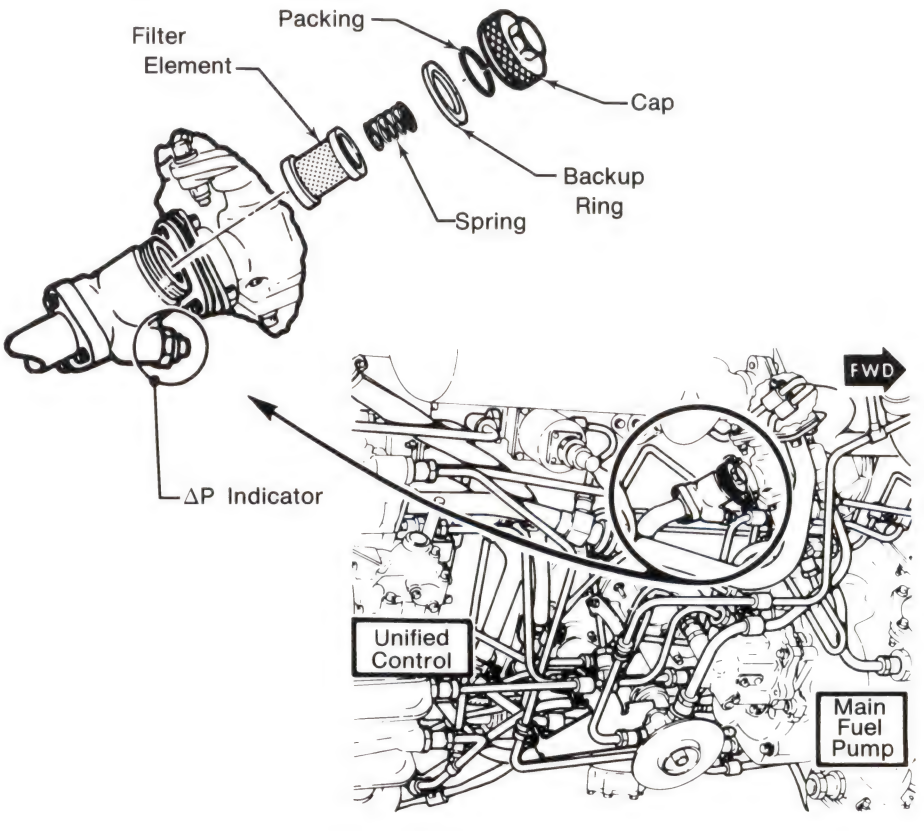


Figure I-22. Fuel Filter Assembly

DERICH SYSTEM FUEL FILTER

The derich solenoid valve is mounted on a bracket inboard the fuel/oil cooler and forward of the UC (Figure I-23). This solenoid-operated valve,

which is controlled by the start fuel flow switch in the cockpit, is used to derich during start.

The derich valve fuel inlet adapter contains a 20-micron filter element which prevents contamination from entering the valve.

The engine and airframe technical orders do not have inspection procedures for the derich valve filter. If the derich filter becomes contaminated, hot starts may be experienced.

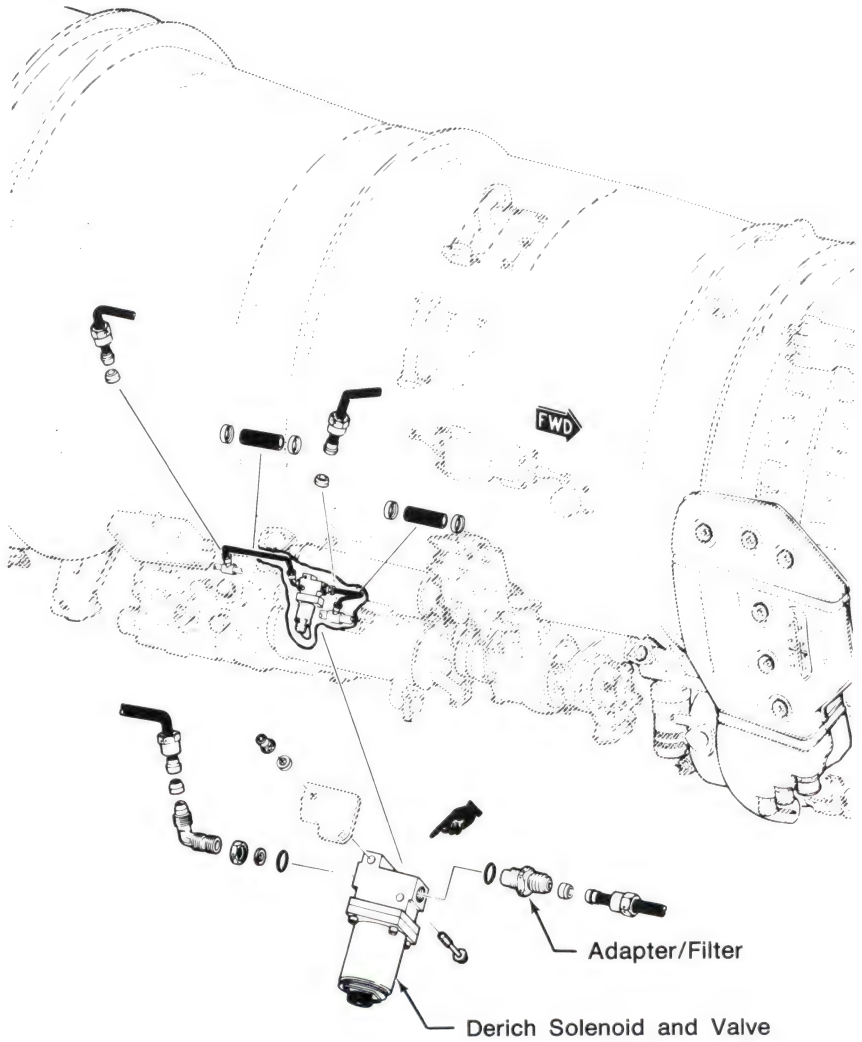


Figure I-23. Derich System Fuel Filter

Engine-Airframe Interfaces

Section II

ENGINE-AIRFRAME INTERFACES

There are many interfaces between the engine and airframe as shown in Figure II-1. Electrical interfaces involve signals which include:

- Mach signal
- Idle area reset/V_{max}
- EEC trim out (off-on)
- Fan speed (N_1)
- EEC fault
- Anti-ice command circuit
- FTIT
- N_2 speed
- A_j position
- Oil pressure
- EHR power
- Derich command circuit.

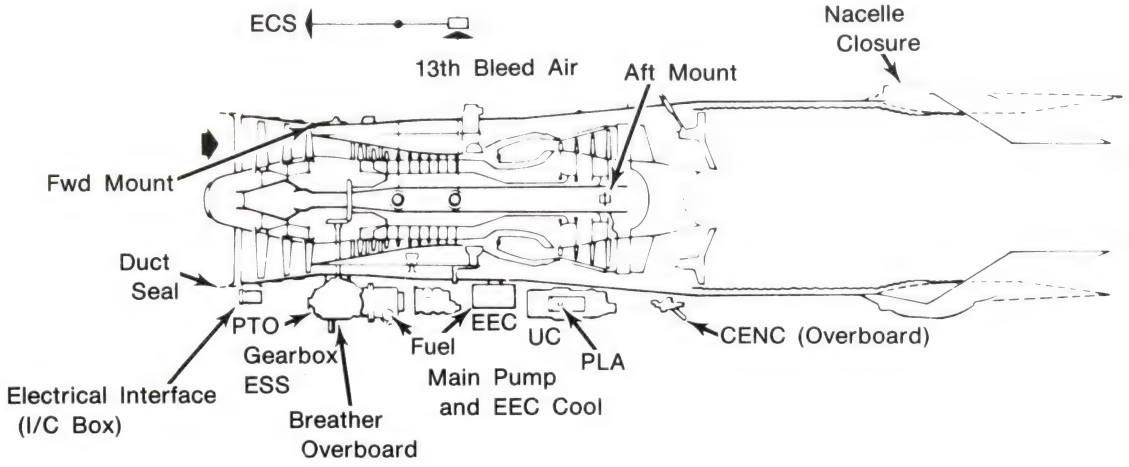


Figure II-1. Engine - Airframe Interfaces

ENGINE AIR INDUCTION SYSTEM

The design of the engine air inlet and duct — the part of the airframe which guides outside air to the engine (Figure II-2) — is critical to efficient engine operation. The engine must receive the proper quantity of subsonic air at the compressor inlet in a continuous, uniform and smoothly flowing pattern or the engine may lose thrust or stall. These airflow conditions must exist throughout the aircraft's operating envelope and during all anticipated atmospheric conditions.

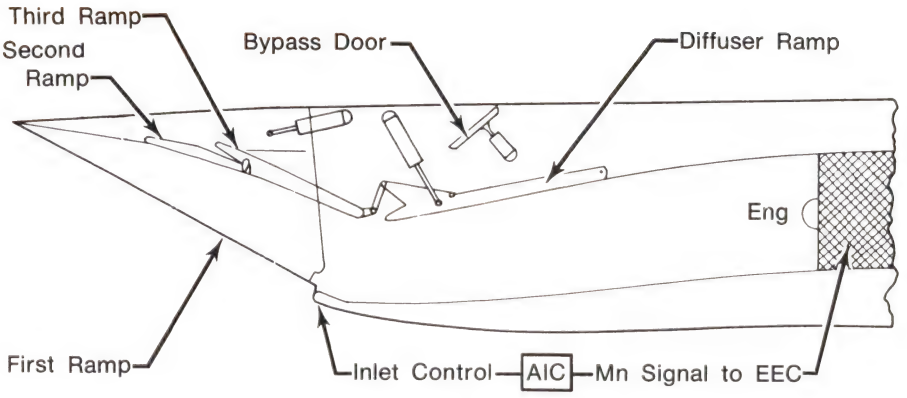


Figure II-2. Engine Air Inlet and Duct

Air Intake

The aircraft has an automatic, independent air induction system for each engine located at the outboard sides of the center fuselage. Each inlet system is made up of the following components: first, second, third and diffuser ramps; airflow bypass door; three actuators; air inlet control; bleed air exit louvers; and foreign object screens. During engine operation, the first ramp pivots up and down to vary the opening of the inlet depending on engine air requirements. The AIC automatically controls ramp movement and the geometric size of the air intake passageway.

Variable Ramps

The variable ramps provide air, at optimum subsonic flow, to the face of the engine fan inlet throughout a wide range of aircraft speeds. Ramp position is controlled by the AIC.

Bypass Door

The bypass door automatically relieves excess pressure in the inlet duct. The AIC positions the bypass door.

Air Inlet Controller

An air inlet controller, one for each inlet, uses angle of attack, aircraft Mach number and other air data system information to automatically schedule the ramps and bypass door throughout the aircraft envelope. The first ramp is locked in the up position until the engine is started.

Inlet Ramp Switch

An inlet ramp switch for each inlet is on the miscellaneous control panel. The switch is lever-locked and has positions of AUTO and EMERG.

AUTO The AIC automatically controls the air inlet system. This is the normal position.

EMERG Removes electrical power from the ramp and bypass door actuators, causing them to move hydraulically to the emergency (ramps locked up and bypass door closed) positions. If hydraulic pressure fails, airloads will force the ramps and bypass door to the emergency position.

AIRCRAFT FUEL DELIVERY SYSTEM

Each engine has a separate feed tank, boost pump and shutoff valve for each engine with crossfeed capability. The emergency generator and boost pump are activated when either main system component is inoperative. The shut-off valves are motor-driven and remain in the last commanded position when electrical power is removed.

The F-15 fuel feed system (Figure II-3) can accommodate multiple component failures without fuel interruption. Master caution, L/R boost pump, L/R generator and emergency boost pump cockpit lights advise the operator of system status. With both main boost pumps inoperative and emergency pump capability only, engine throttle setting is limited to non-afterburning. In the lower right-hand corner of the flight envelope (high speed, low altitude) during sustained maximum afterburning, engine fuel consumption may exceed tank transfer rates and gradually deplete the feed tanks. A FUEL LOW light and voice warning, after retrofit, advises the pilot of this condition.

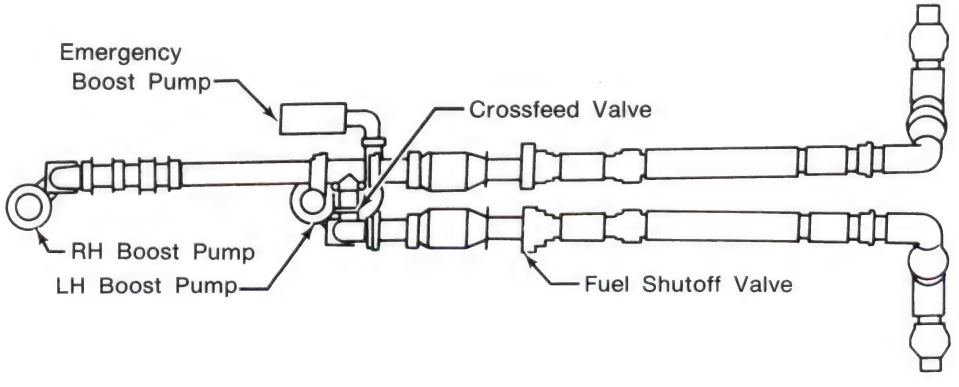


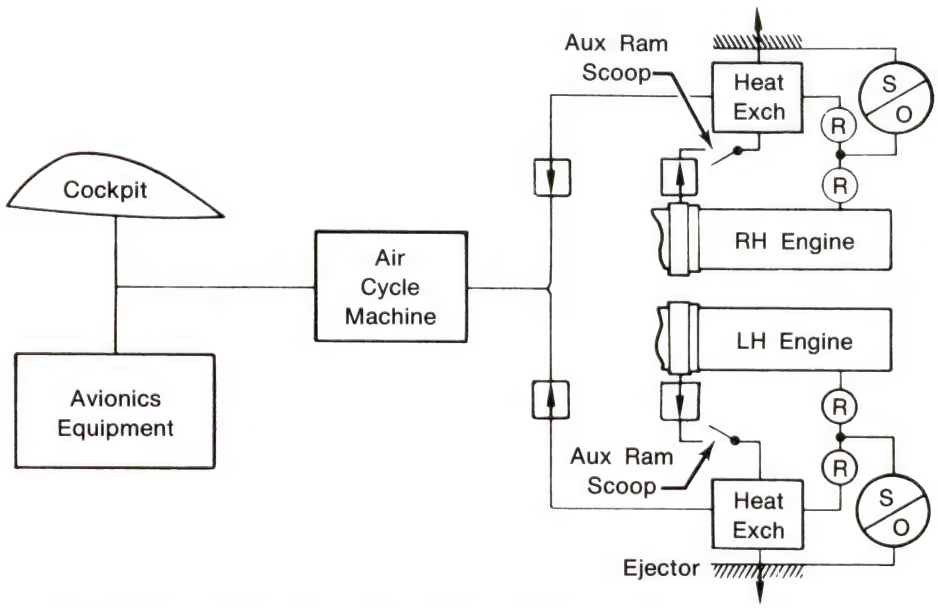
Figure II-3. Aircraft Fuel Delivery System

ENVIRONMENTAL CONTROL SYSTEM

The environmental control system (ECS) (Figure II-4) uses 13th-stage compressor bleed air from both engines. A cooling effects sensor, located in the ECS supply line will illuminate the ECS light if there is insufficient cooling capability. This sensor may also automatically shut down selected

avionics equipment (25 LRUs) during single-engine operation on the ground. If this occurs, the air inlet controller, AIC, will be shut down, removing the Mach number signal normally sent by the AIC to the engine. This could cause the EEC light to illuminate, and it cannot be extinguished by cycling the EEC switch as long as the condition of insufficient cooling exists.

The avionics protection circuitry is disarmed in flight and will also be disarmed by starting the second engine. In order to restore the protection function after flight, it is necessary to be on the ground, to shut down one engine and to cycle the master switch on the shutdown engine. Cycling the master switch will reset the engine run relay, thereby restoring the single-engine operation indication.



- Check valves prevent crossflow between engines
- Cockpit switch controls engine selection — L/R/both
- Shutoff valve is located in the engine bay

Figure II-4. Environmental Control System

ENGINE OVERSPEED PROTECTION SYSTEM

The ODU continuously monitors fan speed and rate-of-change of fan speed to prevent a fan rotor overspeed. Its key features include an independent system for each engine and a sensed overspeed or failure in the system which will turn the EEC off and illuminate the EEC cockpit light (Figure II-5).

Since the cause of EEC light illumination cannot be determined by the operator, follow the procedures in the tech order. The EEC cannot be reset if an overspeed was detected by the ODU.

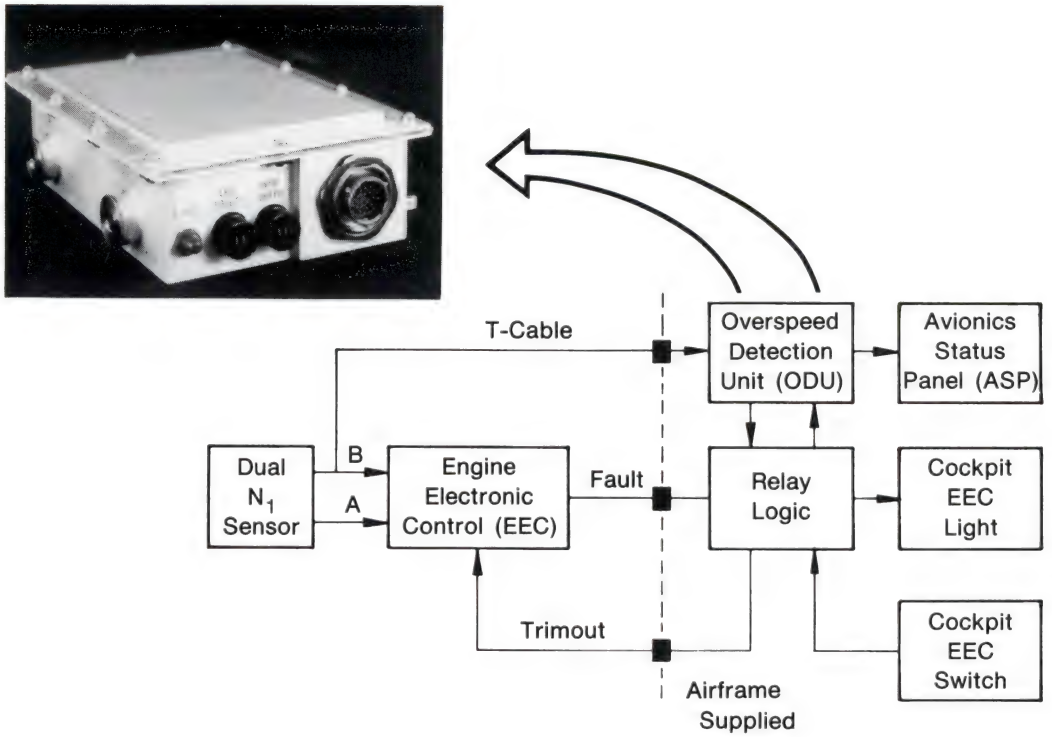


Figure II-5. Engine Overspeed Protection System

COCKPIT INSTRUMENTS

There are five engine-related indicators on the cockpit instrument panel (Figure II-6) to indicate temperature, rpm, nozzle position, fuel flow and oil pressure. A brief description of each is given below.

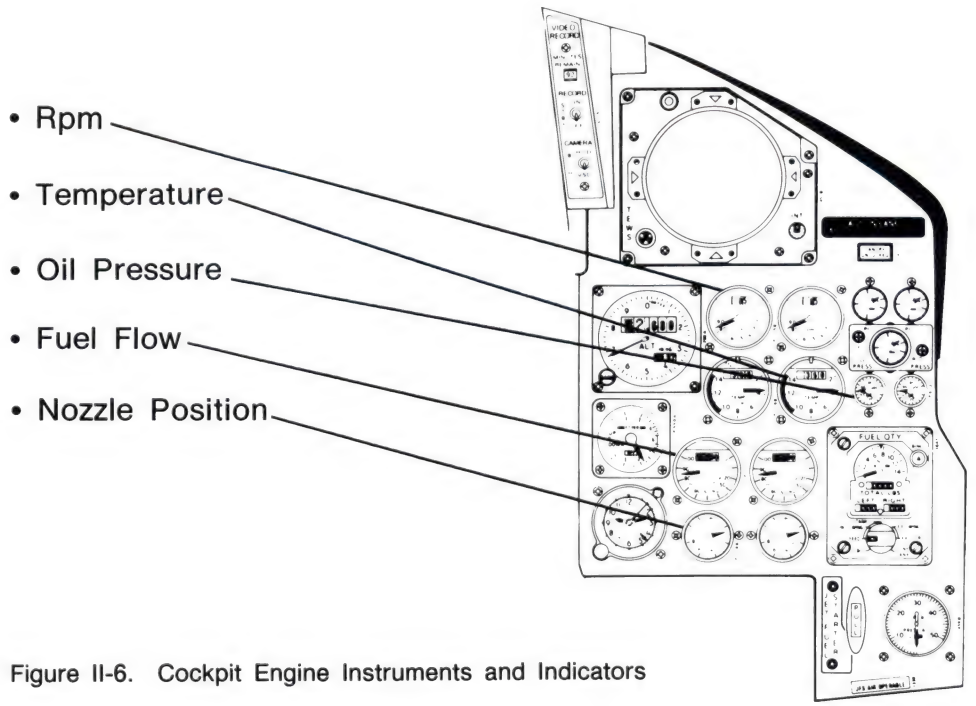
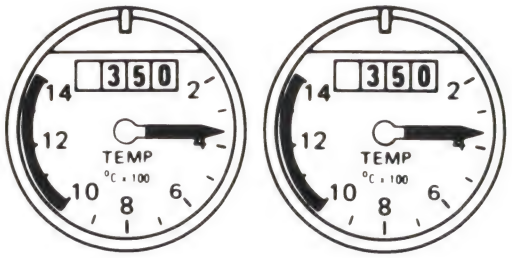


Figure II-6. Cockpit Engine Instruments and Indicators

Temperature Indicator

The temperature indicator (Figure II-7) shows a gas temperature at the mid-stage (fan turbine inlet) of the turbine. Normally referred to as FTIT, it is used to monitor turbine temperature.

A check of other engine instruments for abnormal readings and a cross check with opposite engine instruments can permit the operator to distinguish between engine malfunction or indicator malfunction.



Readout:	Temperature in °C
Accuracy:	± 10°C
Response:	Rapid

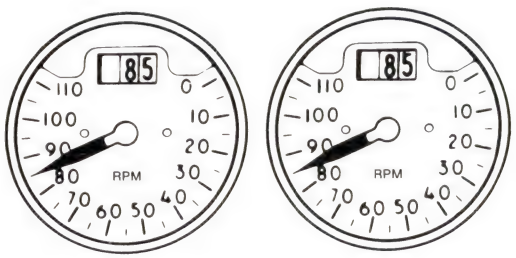
Note: The last digit of the indicator is fixed at 0.

Figure II-7. Temperature Indicator

Rpm Indicator

The rpm indicator (Figure II-8) shows the rotational speed of the high compressor (N_2) in percent of rotor speed. A 100 percent reading is equivalent to 14,000 rpm, but remember you should never see more than 94 percent on the ground. If you do, immediately discontinue the run and troubleshoot for an overspeed.

Like the temperature gauge, crosscheck other indicators of one engine with indicators for the other engine to distinguish between engine malfunction or indicator malfunction.



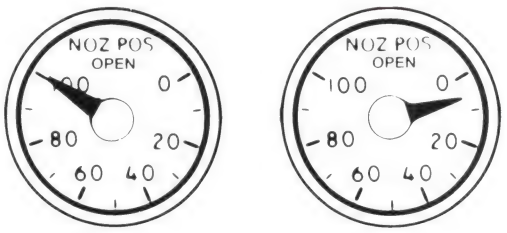
Readout:	Percent rpm
Accuracy:	± ½%
Response:	Rapid

Figure II-8. Rpm Indicator

Nozzle Position Indicator

The nozzle position indicator (Figure II-9) shows nozzle position in percent. The max area (open) equals 100 percent, the minimum area (closed) equals 0 percent.

This is an important cockpit indicator, particularly when selecting or operating the afterburner. It provides the cockpit with the only feedback on an afterburner condition. The readout indicates commanded position of the nozzle. In the event of a nozzle drive system failure, the actual position may differ from the indicated position. Failure of the indicator to show nozzle opening during afterburner operation could be due to a nozzle/engine control malfunction or a failure of the indicating mechanism. Unlike FTIT and rpm, it is not possible for the operator to assess the fault.

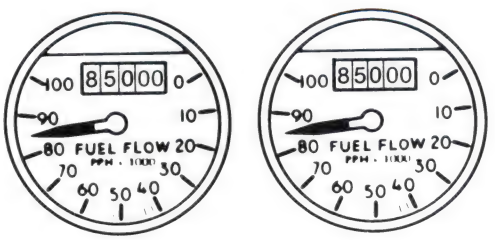


Readout:	Percent
Accuracy:	± 2%
Response:	Rapid

Figure II-9. Nozzle Position Indicator

Fuel Flow Indicator

The fuel flow (Figure II-10) indicator measures total fuel flow. It is designed to permit the pilot to achieve an optimum cruise fuel flow setting for the engine. The response characteristics are slow. On a typical idle-to-max throttle transient, it may take up to 30 seconds for the fuel flow indicator to stabilize.

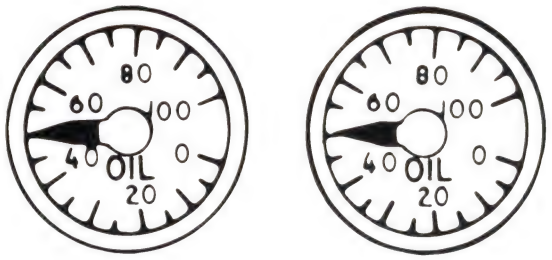


Readout:	Pounds of Fuel Per Hour (pph)
Accuracy:	Varies Depending on Flowrate
Response:	Slow

Figure II-10. Fuel Flow Indicator

Oil Pressure Indicator

The oil pressure indicator (Figure II-11) shows engine oil pressure. It is a steady-state instrument allowing the operator to monitor oil system pressure. It is a reliable indicator. If pressure drops or fluctuates during operation, shut down and consult appropriate tech data.



Readout:	Pounds Per Square Inch (psi)
Accuracy:	± 1 psi
Response:	Rapid

Figure II-11. Oil Pressure Indicator

COCKPIT LIGHTS

There are four engine-related lights on the cockpit instrument panel (Figure II-12) that indicate the operation of the engine electronic control (left and right engines), total operating temperature (high) and oil pressure.

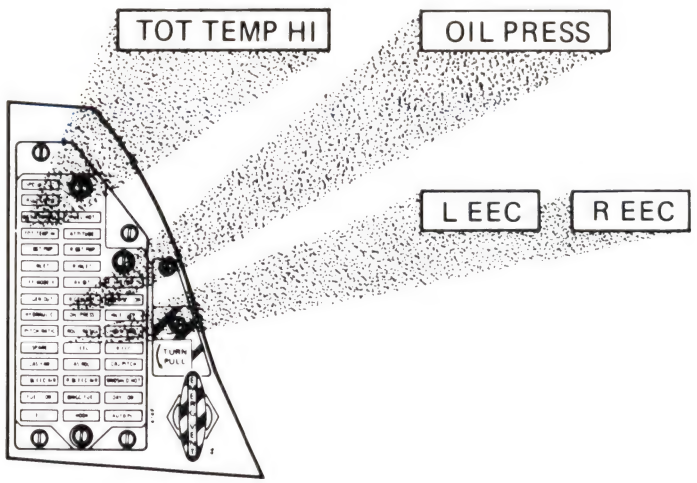


Figure II-12. Cockpit Instrument Panel Lights

EEC Fault Lights

The EEC fault lights alert the pilot that EEC has detected a fault. Possible causes include a faulty EEC, faulty engine sensor(s), failed air inlet controller (loss of mach signal) or a detected overspeed.

Not all EEC faults result in fault light illumination. The EEC self-detection logic is comprehensive, but not complete. For example, a total loss of electrical power to the EEC will not permit light illumination. The EEC logic to detect faults would be inoperative under this condition.

High TOT Temperature Light

The TOT temperature (high) light indicates that total temperature in the inlet duct has reached approximately 170°C. Keep in mind:

- This is equivalent to Mach 2.3 to Mach 2.4
- Engine operation is limited to one minute
- Extended operation will affect engine life
- Light illumination does not shut down other aircraft or engine systems.

You should not see this light illuminate on the ground.

Oil Pressure Light

The oil pressure light indicates low oil pressure. It illuminates when oil pressure has dropped below 8 psi. If this occurs, immediately discontinue the run and troubleshoot the oil system.

ENGINE BAY FIRE WARNING

Engine bay fire detection is provided by sensor loops which are located in each engine compartment. These sensors provide a warning signal indicating a compartment overheat (flashing warning light) or fire warning (steady warning light). The fire detection loops extend past the rotating parts of the engine and beyond all fuel lines. Sensors are not located around the engine nozzles since this area is not considered part of the primary structure. (See Figure II-13).

There have been several instances of engine fires caused by misassembling the nozzle (discussed later in this book), resulting in hot gases being directed into the engine compartment. The resultant fire could not be detected since the sensor loops were forward of the fire and not subjected to sufficient temperature to generate a warning signal. These fires were generally detected and reported to the pilot by his wingman. T.O. changes have been implemented to prevent the nozzle misassembly which resulted in these fires.

Since you don't have a wingman on the ground, your fellow mechanics outside the cockpit are the only ones at the sound suppressor who can detect the problem during A/B operation.

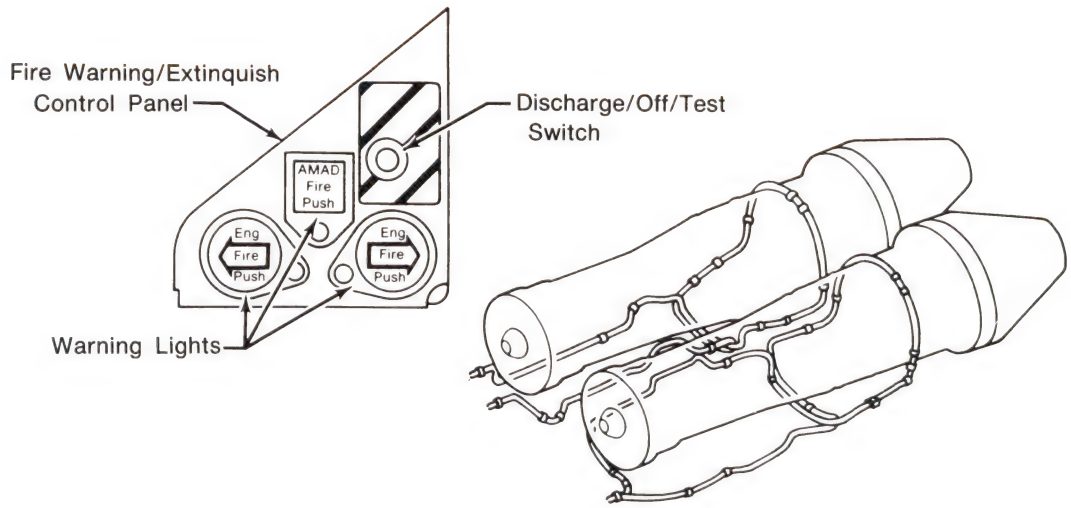


Figure II-13. Engine Bay Fire Warning System

Power Takeoff Shaft

The PTO shaft (Figure II-14) is the mechanical link between the AMAD and the engine gearbox. During engine start or motoring, power flows in series from the JFS through the CGB, AMAD, PTO shaft and the engine gearbox to rotate the high compressor spool (N_2) of the engine. When the engine is running on its own power, the power flow reverses. The N_2 rotation is transmitted through the engine gearbox and PTO shaft to the AMAD. There, the power is distributed by the gear train to drive airframe-mounted equipment. Engine power is precluded from driving the JFS by an overrunning clutch between the accessory drive and the CGB.

The PTO shaft incorporates metal bellows near each end to compensate for angular tolerances between AMAD mounting positions and the engine gearbox.

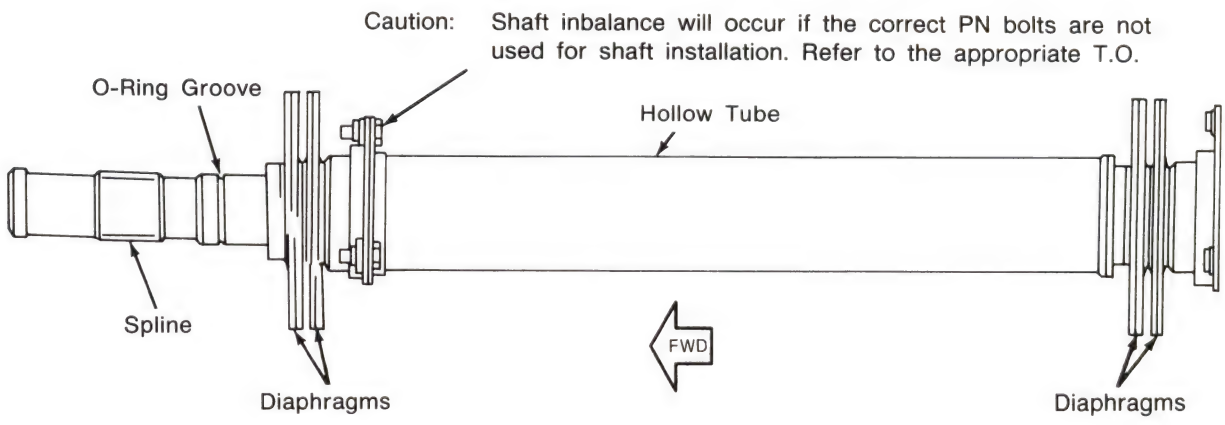

Caution: Shaft inbalance will occur if the correct PN bolts are not used for shaft installation. Refer to the appropriate T.O.
O-Ring Groove
Hollow Tube
Spline
FWD
Diaphragms
Diaphragms

Figure II-14. PTO Shaft

Ground Operations & Trimming

Section III

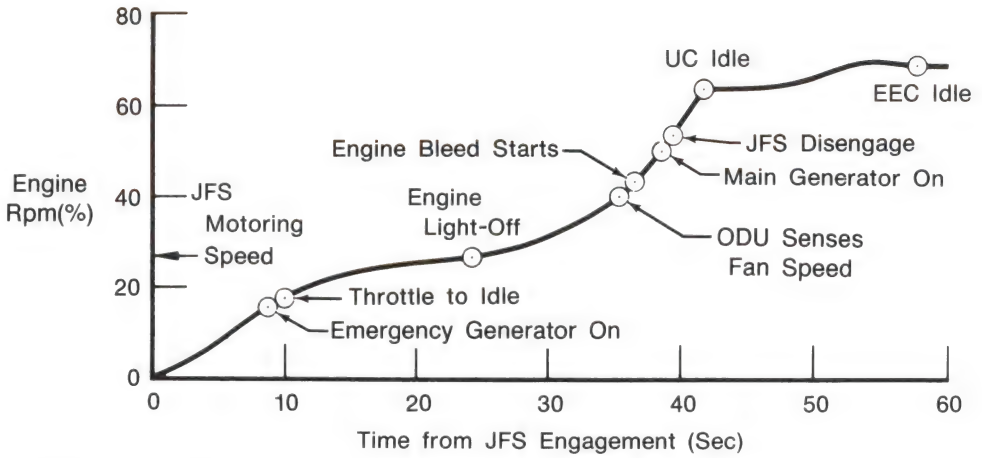


Figure III-1. Engine Start Sequence

STARTING

An awareness of the start sequence (Figure III-1) will help you understand what the EEC light means. The normal sequence of events is given below. All rpm's and times are approximate.

- Rpm=0% t=0 — JFS engagement with audible decrease in JFS whine.
- Rpm 15-18% t=8-10 sec — Emergency generator is powered up. Rpm gauge starts to move.
- Rpm 18% t=12 sec — Position throttle to idle. It takes about 10 seconds to fill the fuel lines and spray a fog of fuel into the combustor.
- Rpm 25-28% t=22-27 sec — Engine light-off occurs. FTIT starts to rise.
- Rpm 40-42% t=35 sec — EEC light may flicker. Opposite engine EEC light will turn on if ODU is installed. This is normal because the ODU has powered-up before minimum speed was reached.
- Rpm 42-44% t=36-38 sec — ECS bleed valve opens. Cooling air begins to flow to the cockpit.
- Rpm 48-52% t~40 sec — A/C main generator is on, JFS disengages, EEC power on.

Note: In this range, if the EEC should power-up slightly before the main generators, the EEC light will illuminate. Since the main generators power the AIC, which supplies a Mach signal to the EEC, the EEC is detecting the absence of a Mach signal. This is not abnormal. Also, if ECS cooling air is not adequate you will observe an ECS light, which will shut down the AIC and illuminate the EEC light. Again no problem. Continue the start

cycle. The EEC lights should extinguish after the EEC switches are cycled with both engines running. If not — troubleshoot.

- Rpm=60-65% t~40-45 sec — UC idle. Rpm varies with trim level and ambient conditions.

- Rpm=66-68% t~60 sec — Engine is slowly trimming up from UC idle to EEC controlled, closed-loop idle. You should be able to hear this increase. It confirms EEC closed-loop idle operation.

Remember: 30 seconds after the main generator comes on line, fuel flow will increase 100 pph. This corresponds to the "high" position of the start fuel switch. EEC light illumination during the start cycle, either flickering or steady, does not indicate abnormal operation if lights remain out after cycling the EEC switches with both engines running.

GROUND IDLE OPERATION

The EEC senses fan speed and requests the UC to regulate fuel flow to maintain a constant, temperature-corrected fan speed. This assures stable engine rpm and sufficient engine stall margin during low-power throttle transients on the ground and at low altitudes in flight.

Closed-loop idle, after an EEC switch cycle, can take up to one minute to trim the engine up from the UC level of idle trim. This increase is generally audible and is always preceded by an approximate 0.5% rpm increase, which occurs as soon as the EEC is turned on. This initial increase is in response to the nozzle opening and should not be mistaken for closed-loop idle. Any further change in rpm is due to the EEC monitoring T_t2, P_b and N_1 and then adjusting rpm to the appropriate level (Figure III-2).

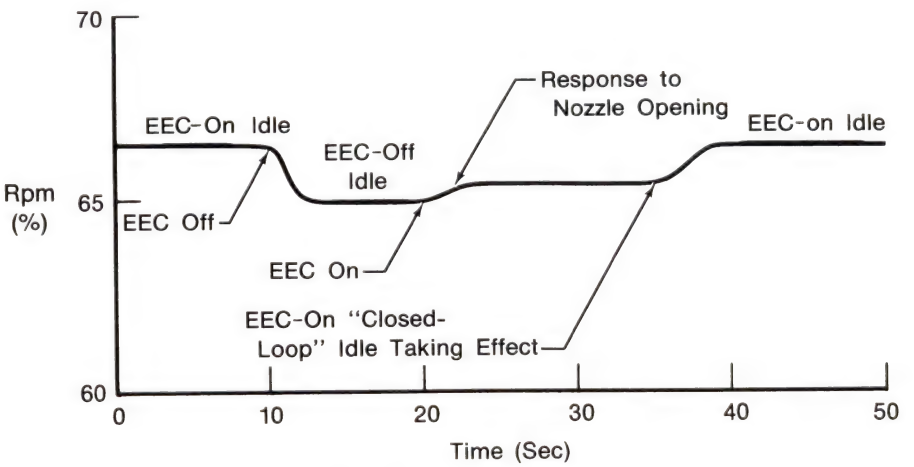


Figure III-2. Ground Idle Sequence

Idle Area Reset

In response to a signal from the aircraft when the landing gear handle is down and the throttle is at or near idle, the EEC passes the signal to the UC to open the nozzle. The open nozzle reduces standard-day idle thrust by 30 percent.

OPERATIONS IN ICING CONDITIONS

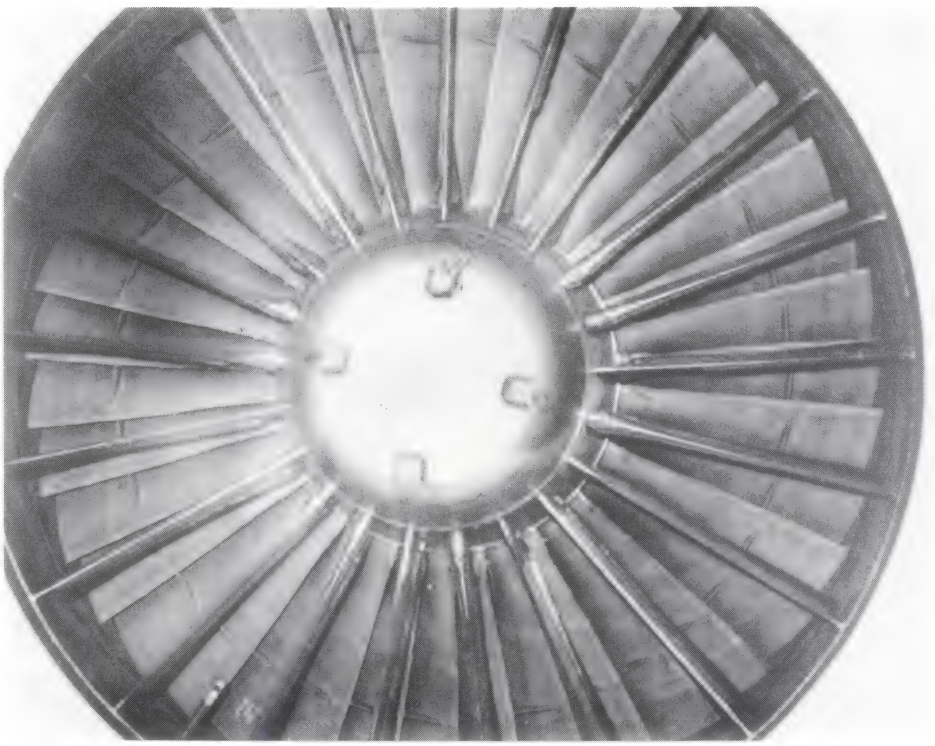


Figure III-3. Ice-Covered Inlet

The best approach is to avoid icing conditions (Figure III-3) whenever possible, but if you can't, here are some things you should know about icing:

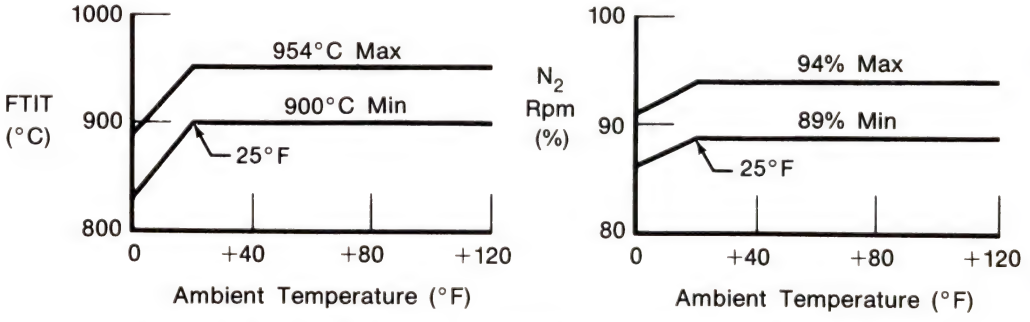
- The most critical condition is ambient temperature between 20 and 45°F (−6.9 to 7.2°C).
- The engine anti-ice system is designed to prevent ice accumulation. It is not a de-icer. It is important to turn anti-ice on before you enter icing conditions.
- During ground operations, avoid running over standing water.
- During ground taxi, ice buildup on the inlet lips probably indicates ice buildup on the engine face and potential FOD.
- The inlet ice detector is located in the left-hand duct only. The cockpit ice light warns of ice accumulation on the detector. This usually precedes engine face ice accumulation.
- If ice FOD occurs, damaged fan blades must be replaced or repaired (blended).

TYPICAL ENGINE GROUND OPERATING CHARACTERISTICS

At MIL power, the engine is being controlled to either an rpm level or an FTIT level, depending upon ambient temperature. Above 25°F, FTIT is controlled to a level between 900 and 954°C, and rpm will be 89 to 94 percent. Below 25°F, rpm is scheduled to maintain constant airflow, and FTIT will be whatever is required to maintain that rpm. The scheduled rpm and FTIT levels are both externally adjustable so that the engine's performance may be maintained as parts wear. In general, older engines will run to a higher rpm and FTIT than newer engines.

During steady-state MIL power operation, you should not exceed 954°C FTIT, 94 percent rpm and 30 percent A_j. If any one of these limits are exceeded, discontinue the run and troubleshoot the problem per the tech order. See Figure III-4.

Note: Afterburner operation should not change these gas generator (core) parameters, though they may fluctuate very slightly upon afterburner selection. The nozzle, of course, sequences open.



- FTIT should be 900-954°C at an ambient temperature of 25°F or above.
- Rpm should be 89%-94% at an ambient temperature of 25°F or above
- FTIT and rpm decrease relative to the above values below 25°F

Figure III-4. Operating Characteristics at Military Power or Above

Total airflow through the F100 is approximately 225 pps (pounds per second). To illustrate how much air passes through the engine, think about a hangar 300 feet long, 150 feet wide and 50 feet tall containing 2,250,000 cubic feet of air weighing 172,000 pounds. The F100 engine at MIL power would evacuate the air from this hangar in about 12 minutes. It would evacuate a standard size, three-bedroom (2,000 square feet) home in five seconds.

EXHAUST NOZZLE POSITION

In response to a signal from the aircraft when the landing gear is down or during ground operation, the EEC will request the UC to open the nozzle position to 75-90 percent at idle (Figure III-5). As throttle position is increased, the nozzle will ramp closed until it reaches the 3-17 percent area at mid-range. The nozzle will maintain this position until approximately MIL power. At MIL, the nozzle will vary in an attempt to optimize trim. As the throttle is advanced into afterburner, the nozzle will start ramping open and at maximum A/B the nozzle will open to approximately 75 percent.

The purpose of idle area reset at idle on the ground is to minimize idle thrust. Opening the nozzle reduces idle thrust by approximately 30 percent. This saves wear and tear on the aircraft brake system and shortens the required landing distance.

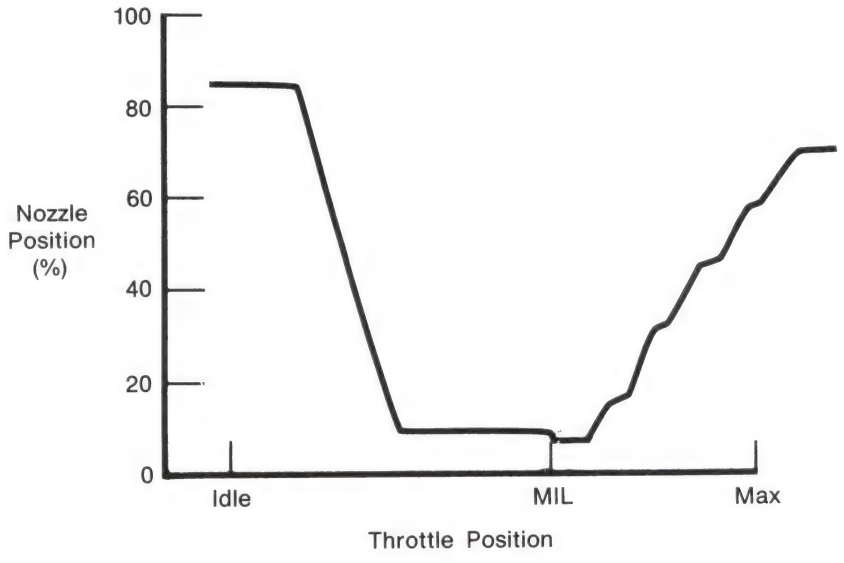


Figure III-5. Exhaust Nozzle Position

TRIMMING THE F100

EEC Closed-Loop Idle Check

The EEC schedules idle to maintain a constant N_1 or minimum P_b (Figure III-6). The primary functions of the closed-loop idle features are to maintain idle speeds high enough to: (1) provide stall-free operation at idle or on accelerations from idle throughout the flight envelope, and (2) maintain idle thrust at the desired level.

This control function is not trimmable, but must be checked to ensure proper operation. Since idle is scheduled to maintain a constant N_1 or minimum P_b, there are conditions under which idle N_1 will be higher than the

required band of 4,300 N_1 ±100 rpm (43±1%) with the system functioning correctly. This occurs when idle is being scheduled to maintain P_b greater than 47 psia, which is possible on the ground only at high altitude bases (Figure III-6).

Other reasons for idle operation outside the check band could be:

- Erroneous instrumentation (includes the fan eddy-current sensor)
- UC idle trim too high
- T_t2 sensor not connected or shorted
- Dual N_1 sensor/cable problems
- EEC fault (or associated electrical anomaly).

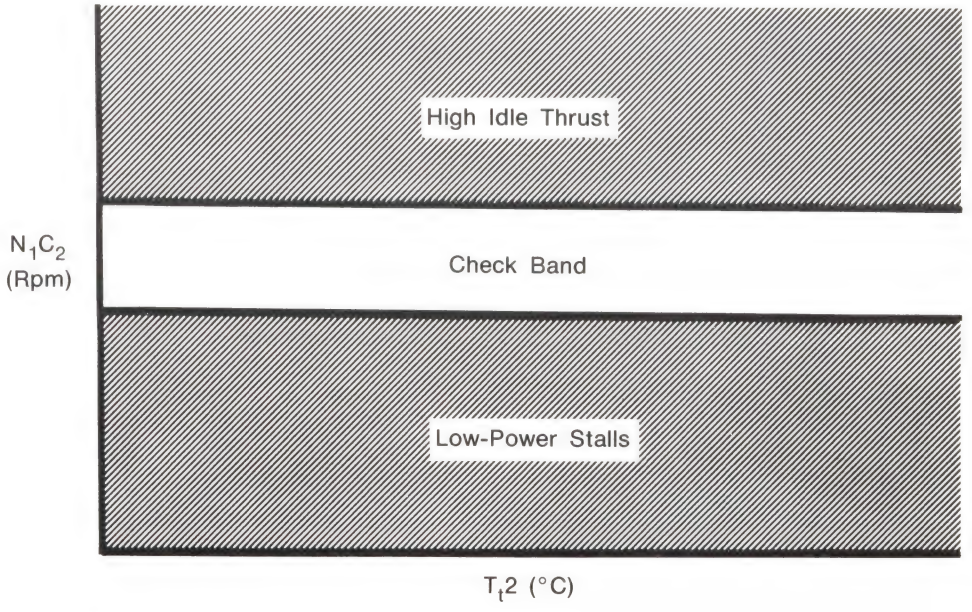


Figure II-6. EEC Closed-Loop Idle Check

RCVV Schedule Trim and Check

The rear compressor variable vanes are scheduled by the UC as a function of N_2 and $T_t2.5$. The primary function of RCVVs is to provide high compressor stall margin at all operating speeds. Operation with RCVVs more axial than the check band can result in stalls and/or fatigue damage to compressor blades. Operation with RCVVs more cambered than the check band can result in high compressor overspeeds or low performance. Improper MIL power engine pressure ratio can result if the RCVVs are not trimmed into the band (Figure III-7).

If the RCVVs cannot be trimmed as specified in the T.O., the most probable causes are:

- Erroneous instrumentation
- Worn RCVV hardware
- Misrigged feedback cable
- Failed $T_t2.5$ or N_2 sensor
- UC malfunction
- Misrigged RCVV actuator.

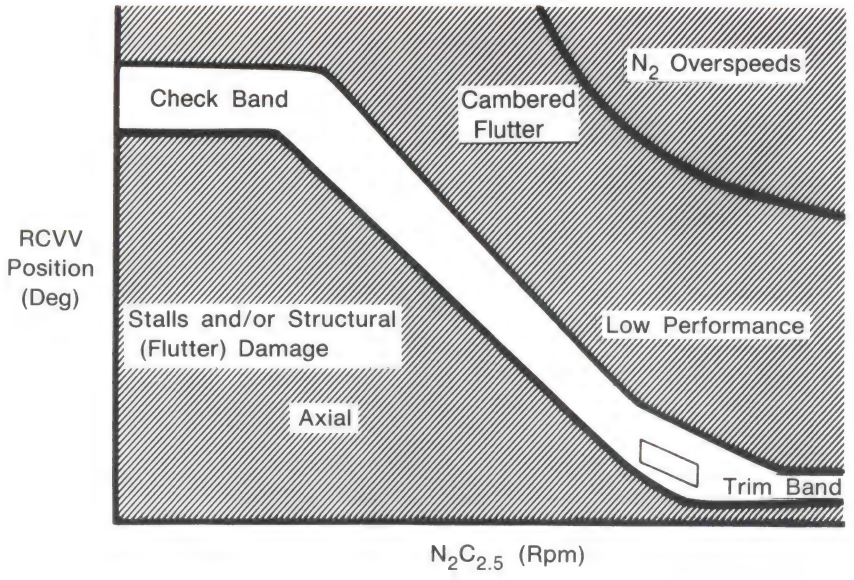


Figure III-7. RCVV Schedule Trim and Check

CIVV Schedule Check

The compressor inlet variable vanes are scheduled by the EEC as a function of N_1 and T_t2. The primary function of CIVVs is to provide fan stall margin at all operating speeds. Operation with CIVVs off schedule (either too axial or too cambered) will not necessarily result in fan damage, but will result in improper engine trim, low performance, A/B blowouts and stalls. The CIVVs are not trimmable, but must be checked to ensure proper scheduling by the EEC (Figure III-8).

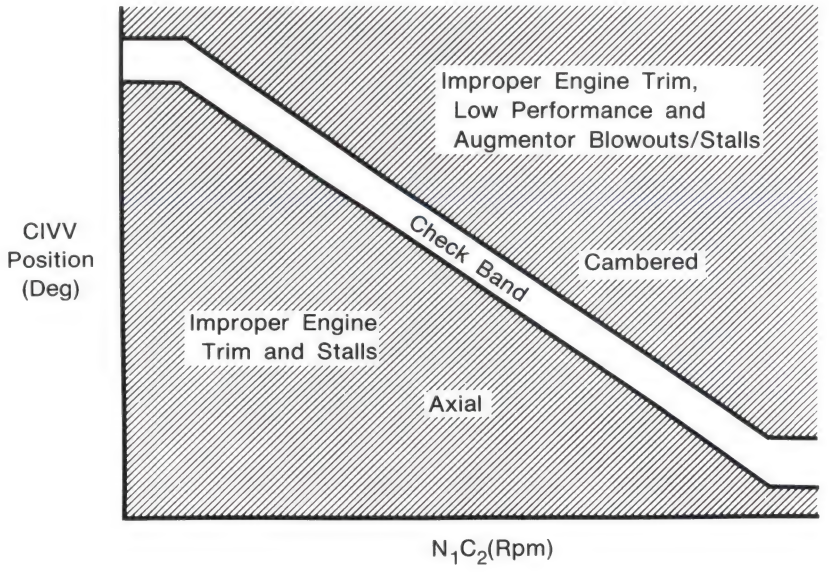


Figure III-8. CIVV Schedule Check

If the CIVVs are not in the check band, the most probable causes are:

- Erroneous instrumentation
- Failed CIVV master actuator
- Misrigging (primary or slave actuator)
- EEC problem
- Dual N_1 sensor/cable problems
- T_t2 sensor not connected or shorted.

UC Idle Trim (EEC Off)

The primary function of UC idle is to provide safe, stall-free operation at idle should the EEC fail. Trimming UC idle too low can result in cockpit smoke and/or low-power stalls during EEC-off operation. Trimming UC idle too high restricts the ability of the EEC to schedule closed-loop idle properly and can result in excessive idle thrust (Figure III-9).

Idle mistrim can result from:

- Erroneous instrumentation
- Failed $T_t2.5$ or N_2 sensor
- UC problem.

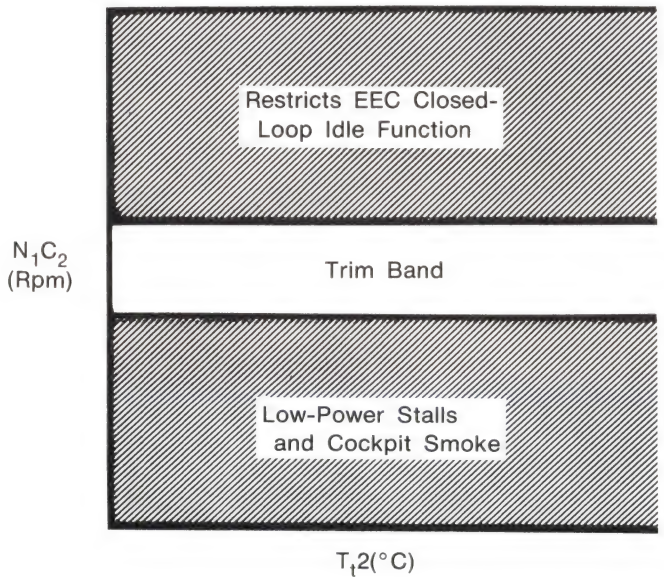


Figure III-9. UC Idle Trim (EEC Off)

UC FTIT Trim

The UC FTIT trim (commonly called trimout) sets the basic level of FTIT or MIL power with the EEC off. This trim also provides engine overtemp protection when the EEC is trimout. A higher than normal N_2 speed during UC FTIT trim could be indicative of an engine problem and should not be allowed to persist without troubleshooting (Figure III-10).

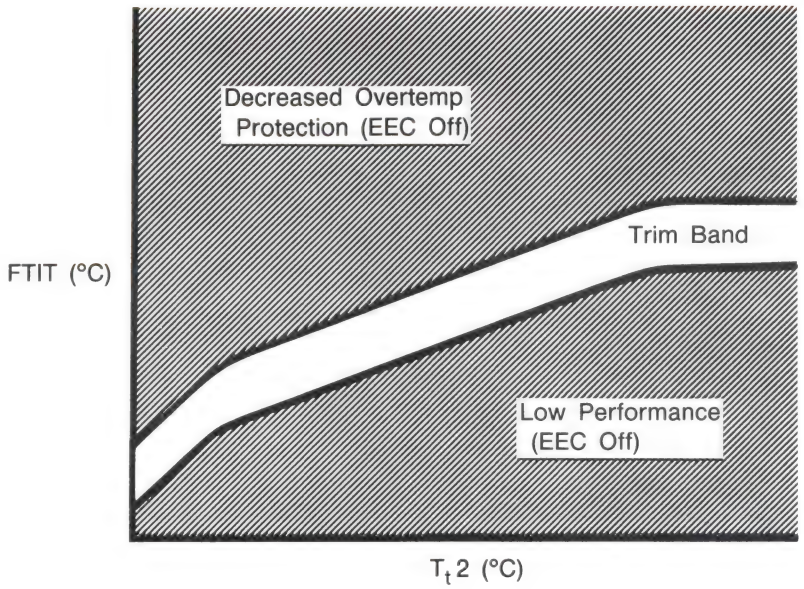


Figure III-10. UC FTIT Trim

UC FTIT mistrims can result from:

- Erroneous instrumentation
- Bad FTIT probes or signal
- RCVV too cambered
- UC malfunction.

EEC Trim

When at MIL power or above, the EEC controls engine performance by scheduling to the N_2 schedule or FTIT limit. The engine operates to only one at a time.

EEC N_2 Trim

The N_2 schedule is trimmable and must be set correctly for proper engine operation. Engine pressure ratio is the parameter used to gauge proper trim of the N_2 schedule since it is representative of engine thrust and stall margin.

The engine operates on the N_2 schedule provided the FTIT limit (EEC click setting) has not been exceeded. During ground operation the engine will run on the N_2 schedule if OAT is approximately 20°F or lower and the FTIT limit is raised (to 11 clicks). The N_2 schedule can then be trimmed to obtain the desired engine pressure ratio.

If OAT is higher, the FTIT limit may be reached and the N_2 schedule cannot be properly adjusted without: (1) raising the FTIT limit (to 11 clicks) and (2) inputting a "false" T_t2 signal to the EEC. This allows the engine to run on the N_2 schedule that is being trimmed.

In general, undertrimming the N_2 schedule will cause low thrust and A/B blowouts/auto-ignition stalls. Overtrims will cause A/B initiation, sequencing or cancellation stalls (Figure III-11).

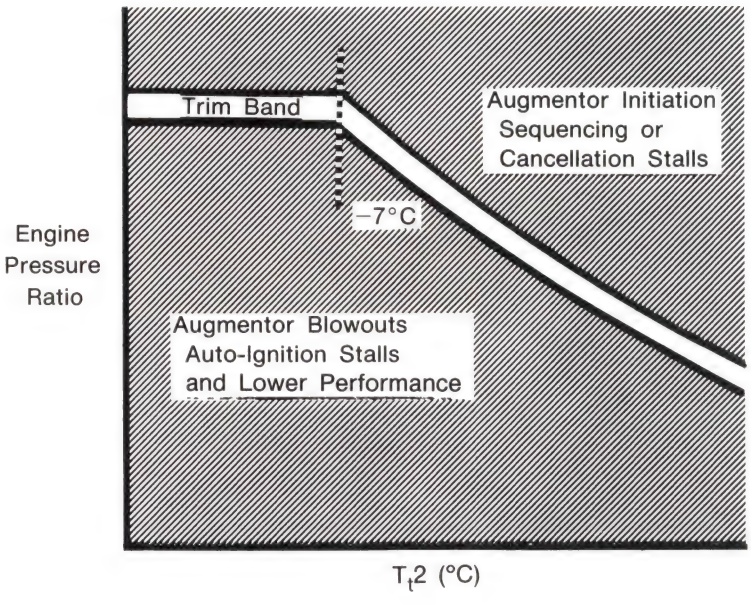


Figure III-11. EEC N_2Trim

EEC FTIT Trim

The FTIT limit is adjustable and must be set correctly for proper engine operation. FTIT limit scheduling is accomplished indirectly by a known relationship of the operating FTIT required for N_2 schedule trim and T_t2.

In general, undertrimming the FTIT limit will cause low thrust. Overtrimming will decrease engine life (Figure III-12).

Mistrims can result from:

- Erroneous instrumentation
- RCVV/CIVV out of limits
- Bad FTIT probes or signal
- EEC problem.

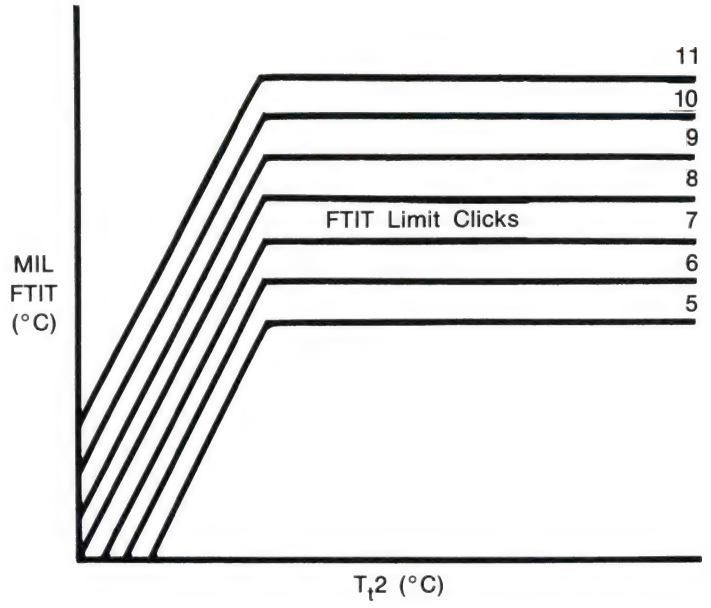


Figure III-12. EEC FTIT Trim

Thrust Parameter Check

An intermediate (MIL) power check has been instituted to verify engine performance while operating on EEC FTIT control. This check prevents low thrust while ensuring acceptable engine life.

Engine pressure ratio, N_1 rpm and T_{amb} values at MIL power are compared to trim tables to determine a calculated (equivalent) thrust level. Engines exhibiting low thrust levels will require additional EEC FTIT clicks and/or possible troubleshooting. This new check is significantly more accurate than using EPR alone, which was used in pre-1979 trimming (Amb EPR trim). It also can be used to pinpoint engine hardware deficiencies while maintaining a minimum thrust level.

Low thrust can be caused by:

- RCVV system looseness
- False EPR mistrim
- Faulty/FTIT probes or signal
- Core module internal clearances (bowed rotor, abradable wear, inefficient turbine, etc.)
- Anti-ice or start bleed system malfunction.

A/B Fuel Flow Trim (W_{ft}/P_b)

The UC provides fuel flow to the A/B as a function of PLA, P_b and T_{t2}. Proper trim of the A/B fuel flow schedule will ensure trouble-free operation. Only trim when troubleshooting an augmentor anomaly. Overtrimming A/B fuel flow schedule will result in blowouts, rumble and stalls. Undertrims will result in low thrust when the pilot really needs more power (Figure III-13).

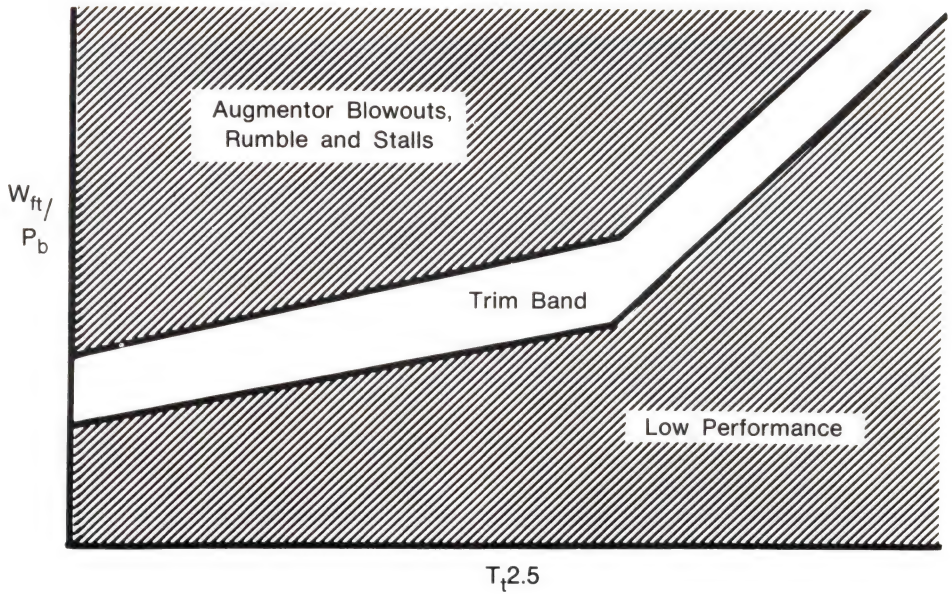


Figure III-13. A/B Fuel Flow Trim (W_{ft}/P_b)

Afterburner mistrims can result from:

- Erroneous instrumentation
- Incorrect fuel specific gravity setting in fuel flow meter (test cell)
- Failed $T_t2.5$ sensor
- UC problem.

The chief cause of mistrims is erroneous instrumentation. If a problem arises when you're trimming, it is a good idea to verify the integrity of your equipment (test cell, A/C instrumentation, trim box, etc.). The instruments are very complex and must be calibrated to ensure a good trim. The engine must be fine-tuned for optimum performance. In other words, AGE can make or break a mission.

UC and EEC Trim Adjustments

The F100 engine trim adjustments and checks required to ensure proper engine operation throughout the flight envelope are listed below (Figure III-14 and III-15).

Parameter	Location	Direction*	Approximate Sensitivity	Range
RCVV	UC	CW-Cambered CCW-Axial	1.5°/Turn	12 Turns
UC FTIT (Max N_2)	UC	CW-Increase CCW-Decrease	59°F(32.7°C) /Turn	18 Turns
N_2	EEC	CW-Increase CCW-Decrease	4 Rpm/Deg	160 Degrees
FTIT	EEC	CW-Increase CCW-Decrease	10°F(5.6°C)/ Click	13** Clicks
W_{ft}/P_b (Max Flow)	UC	CW-Increase CCW-Decrease	(200 Pph) 0.6 Ratio/Click	60 Clicks (3 Turns)
UC Idle N_2	UC	CW-Increase CCW-Decrease	100 Rpm/Turn	10 Turns

Required trim checks (no adjustment available) are:

Parameter	Controlled by
EEC IDLE	EEC
CIVV	EEC

*CW (clockwise); CCW (counterclockwise)
**EECs prior to HSD PN 773098 have a 16-click range

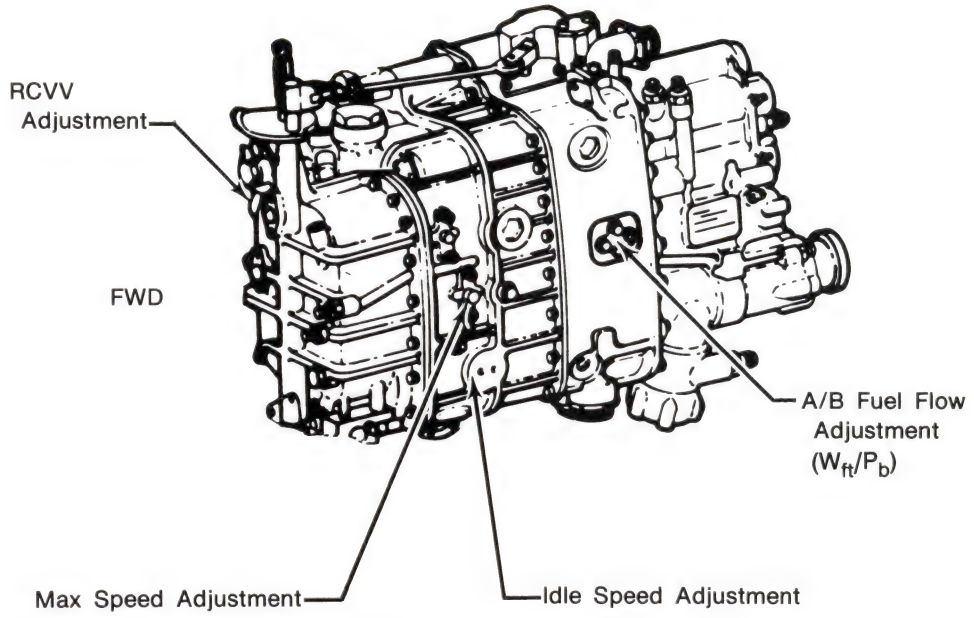


Figure III-14. UC Trim Adjustments

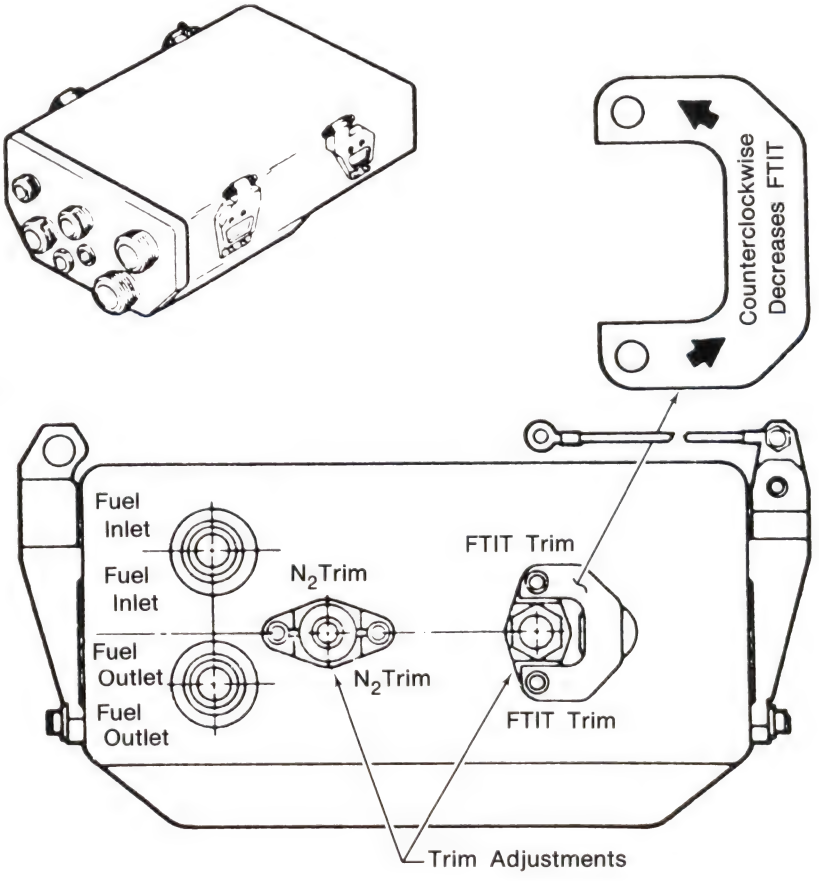


Figure III-15. EEC Trim Adjustments

TRIMMING

Mistrims have resulted in engine operational/durability problems, and of course, increased MMH requirements. Mistrims can be caused by test stand calibration errors, stand-to-engine hook-up errors, pressure line leaks and data reading/recording errors. Any one of these errors can cause a mistrim, and if combined may result in a severe mistrim.

The trim errors are usually subtle and not obvious to the operator. As a result, many engines can be mistrimmed before the problem is noticed. In an effort to eliminate these problems and increase the understanding of F100 engine trim, we have prepared a set of guidelines to explain some of the trim functions and to point out some of the most common mistakes made during trimming. These guidelines are not intended to supersede the T.O.'s and are not inclusive. They should be used as backup information in reviewing and isolating trim problems.

Trim Functions

UC Trims — The UC is designed to control the engine if the EEC is inoperative. Therefore, UC idle, RCVV and intermediate trims are required to permit proper operation in the hydromechanical mode (EEC off).

EEC Trims — The EEC supervises the UC and can be trimmed more precisely. The EEC schedules N_1, N_2 and FTIT limits to maintain optimum operability and performance.

False T_t2 EPR — The purpose of the EPR trim is to ensure stall-free operation at inlet temperatures less than $\approx$35°F. The band width is intentionally narrow to account for measurement inaccuracies. EPR variations within $\pm$ one-band width are considered within normal repeatability. EPR variations greater than $\pm$ one-band width are outside the expected range of repeatability and may indicate that a mistrim has occurred earlier or is about to take place.

FTIT trim — The purpose of FTIT trim is to ensure adequate thrust at the lowest FTIT click setting. The initial level of FTIT trim is established from the FTIT measured during false EPR trim. The ambient EPR check is an additional thrust check to help guarantee that a minimum thrust is maintained.

Afterburner trim — Perhaps the least understood of all trims is afterburner trim. The W_f/P_b trim is intentionally narrow to account for measurement inaccuracies. Variations in W_f/P_b of $\pm$ 4 ratio units are considered normal repeatability. It should be noted that A/B trim is required only after an A/B squawk.

Trim Errors

The most common mistakes made during trimming are described below: Instrumentation errors — By far the most common problem causing mistrim is poor instrumentation. Unfortunately, AGE has not kept pace with the F100 engine, thus inhibiting engine trim accuracy. Periodic calibration

of instruments should be strictly adhered to. Simple validity checks described below should be made prior to and during each trim run. They are quite reliable.

- T_{amb} — It is ironic that in this age of high technology, one of the most difficult parameters to measure is the temperature of the air entering the engine. Since the trim curves assume that T_{amb} is known within ± 1°C, redundant measurements of T_{amb} using relatively inexpensive thermometers are recommended to ensure a reliable indication of T_{amb}.
- P_{amb} and P_t2 — Redundant P_{amb} is recommended. Call the tower. P_t2 should always be less than P_{amb} during engine run at MIL power (0.1 to 0.2 psig normal; 0.2 to 0.4 in. Hg. normal).
- P_t6 — Leak check P_t6 versus P_{ab}. The purpose of this check is to detect P_t6 leaks or problems. If P_{ab} is equal to or greater than P_t6, overtrim will occur, exposing the engine to stalls.

Line leaks and hookup problems — Calibration of test stand gauges may not be enough. The supply lines from the engine to the stand may have leaks or not be properly connected. Be sure to inspect and leak check these lines periodically. It is also easy to cross lines even though they are identified. Be sure all lines are hooked up correctly.

Substitution of parameters — There have been cases where ambient temperatures or pressures are substituted for measured values. This can cause major discrepancies in engine trim.

Leaving air source/anti-ice on — Turn off air source and anti-ice during EPR trims (false and ambient).

Incorrect N_1 measurement — Do not use N_1 measured during false EPR trim to enter N_1, EPR table. Use N_1 measured during ambient EPR trim.

Data reading and recording — Incomplete and inaccurate data recording accounts for many mistrims. This problem will never go away, but it can be helped by reviewing the trim sheets and making sure the correct T.O. and limits were used. Write down which T.O. was used. This will save time, and mistakes can be more easily identified. Maintain complete historical files on engines for use in future trims and troubleshooting.

Component changes — Comply with the "DOT" chart according to tech data. If a retrim is required it must be a full retrim, not just false or ambient points.

Temperature changes — Ensure that T_t2 used to determine trim limits is consistent with the temperature at the time the data point is taken, i.e., do not record limits before the step, as temperature changes will affect the trim target values.

Measuring fuel pressures — When checking ΔPs (MFP, UC, augmentor wash filter, etc.), the ΔP tranducers in the trim box should be used if possible, as this decreases the amount of error. Using two separate transducers doubles the margin of error. When checking for small bands of acceptable ΔPs this will be significant.

T.O. errors — Pratt & Whitney is aware that T.O.'s have mistakes and, in some cases, lack clear instructions which contribute to trim errors. Your inputs are not ignored. Pratt & Whitney is working to resolve these problems. Please point out discrepancies to your Pratt & Whitney representative and initiate an AFTO Form 22.

Trim Check Guidelines

Here are guidelines for F100 trim checks. Reference numbers correspond to those on the trim sheet (Figure III-16).

1. Prestart static check

   a. Test cell (standard day unit)

      (1) P_t2 (P_{amb}), P_t6, P_{ab} within 0.15 in. Hg of tower P_{amb}. Calculated EPR should check 1.000 ± 0.010.
      (2) T_t2 should be within 1°C of a calibrated thermometer. (Bellmouth screen thermocouple should be shielded, as required per T.O.).
      (3) $T_t2.5$ should be within ± 2°C of indicated T_t2 if engine has not been run within three hours.
      (4) Record P_{amb} and T_{amb} (T_t2).
      (5) Verify P_{amb} with tower during prestart.

If discrepancies are noted, verify proper hookup of system and confirm that the SDU was warmed up 45 minutes prior to test, as defined in T.O. 2J-F100-26/36-3.

   b. Sound suppressor (trim box)

      (1) Ensure thumb screw is open on P_{amb}.
      (2) Ensure prestart calibration is adjusted to P_{amb} level.
      (3) EPR calculation. Check for 1.000 ± 0.010. If not in this band recheck P_t6 calibration with P_{amb}. Adjust P_t6 to agree with P_{amb}. If EPR does not indicate within 1.000 ± 0.010, reject trim box.
      (4) Ensure T_{amb} probe is not near ECS, JFS or engine exhaust, or directly in sunlight.
      (5) Verify P_{amb} with tower during prerun.

2. RCVV Trim

   a. Test cell/sound suppressor

      (1) Periodically compute N_1 corrected to T_t2 and N_2 corrected to $T_t2.5$ using Theta (θ) tables in T.O. 2J-F100-21/31-2, WP 01200, Table 1.

      (2) Computed values should be approximately 40 rpm of indicated values for N_1 corrected and N_2 corrected on standard day box or trim box.

If discrepancies are noted, call PMEL for instrumentation/calibration check.

3. Verify indicated FTIT level is between 904-919°C at five clicks.

4. P_{ab} versus P_t6 check band

   a.Test cell only

      (1) Ensure within limits of T.O.

      Limits in T.O. have appropriate tolerance bands built in. If P_t6/P_{ab} exceeds the limit, troubleshoot per instructions in T.O. 2J-F100-21/31-2, WP 01100. The check may require interpolation of values.

      Example: P_t6 = 74.20 in. Hg P_{ab} = 36 psia. This combination is out of limits per Table 9 of T.O. 2J-F100-21/31-2, WP 01100.

      Note: If P_{ab} is being measured in in. Hg., a quick check can be made by comparing P_t6 to P_{ab}. P_t6 should always be higher.

5. EPR/maximum fuel flow trim (false T_t2 signal check)

   a. Test cell only

   (1)With false signal generator turned on, plug output signal at engine into $T_t2.5$ to stand instrumentation at engine.

   (2)Set variable false signal to −7°C on $T_t2.5$ in cab (an occasional flashing −6 is better than an occasional flashing −8). Once set to −7°C, reconnect $T_t2.5$ normally and input false signal to engine.

   Note: The indicated false T_t2 may shift during this process but should not be readjusted.

   Proper false T_t2 signal to the engine is indicated by N_1 level of 10,030-10,120 rpm (nominal is approximately 10,070 rpm) (100.3-101.2%/100.7 nominal.)

   Always complete the false and ambient EPR trim. Let the trim determine acceptance or rejection of the engine.

6. False EPR (EPR readout check versus calculated EPR)

   a. Test cell/sound suppressor

      (1) Occasionally hand-calculate EPR using recorded P_t6 and P_t2 values to ensure the unit is operating properly. Calculated values should be within ± 0.005.

$$P_t6/P_t2 = EPR$$

7. P_t2 on false (versus P_{amb} check)

   a. Test cell only

      (1) At idle power, P_t2 is approximately the same as P_{amb}. When advancing from idle to MIL, you should notice a minimum P_t2 drop of 0.2 in. Hg (open air or enclosed).

      (2) If open air test cell is used, static P_{amb} and idle P_t2 are approximately the same. Therefore, a comparison of static P_{amb} to the MIL P_t2 recorded in this step should also indicate a P_t2 drop of approximately 0.2 minimum.

      (3) If the test cell is enclosed, there should be a drop in Pcell when advancing from idle to MIL. The amount is a function of cell design. P_t2 at MIL should be equivalent to (Pcell-0.2 in. Hg).

      Corrective action: Check for leaks or loose fittings.

      Ensure bellmouth P_t2 ports are hooked up properly, or if some P_t2 probes are disconnected due to failure, ensure the ports are capped off properly to prevent the good P_t2 probe readings from being biased by P_{amb}.

8. N_1 observed on false T_t2 EPR trim

   a. Test cell/sound suppressor

      (1) N_1 limits on false EPR (FEPR) trim are 10,030-10,120 rpm. Indications on the low side indicate a low false T_t2 signal input (−8, −9°C), on the high side indicate a high false signal input (−6, −5°C). Again, a consistent trend in either direction might indicate a need for false signal generator recalibration (ΔT_t2 or 1°C $\approx$20 rpm N_1 false).

9. N_2 observed on false T_t2 EPR trim

   a. Test cell/sound suppressor

      (1) High N_2 (12,880 rpm (92 percent) or above) is acceptable if ambient EPR is equal to or above level "A" limits. If high N_2 and ambient EPR is below level "A" limits, looseness in the RCVV system may exist. This can be caused by normal wear or misrigging of actuators or the control, bellcrank looseness or incorrect RCVV vane position. See T.O. for corrective action.

      (2) If bellcrank looseness was barely within limits during JEIM check, it is possible that additional wear occurred during the trim run. It wouldn't hurt to check them again.

10. FTIT average on false T_t2 EPR trim

    a. Test cell/sound suppressor

        Normal FTIT on false EPR runs approximately 880-945°C. Indications below 880°C may be indicative of:

        (1) Undertrim due to instrumentation problems on P_t6, P_t2, T_t2 or instrumentation problems called out above.

        (2) FTIT switch selection left in FTIT-corrected position, and/or

        (3) Remaining on individual probes during spread check.

11. RCVV on false

    a. Test cell/sound suppressor

        (1) RCVV trim is designed to provide axial RCVV operation (+4°) during false EPR trim point. A few degrees deviation from +4° may occur during hot day trims (over 80°F). If deviations are larger than 2°, ensure RCVV trim is to the axial side of the trim band (+9210,200 N_2 $C_{2.5}$).

            Note: When false EPR trims are made away from the +4° stop, stall margin in the upper left-hand corner is decreased.

12. ENP (A_j) on false

    a. Test cell/sound suppressor

        (1) False EPR nozzle positions generally run 15-20 percent. Consistent indications above or below this range may indicate instrumentation problems. Troubleshoot accordingly.

            Note: You may see as low as 10 percent on a cold day (below 35°F) and as high as 25-30 percent on a hot day (above 80°F).

13. N_1 observed on ambient EPR

    a. Test cell/sound suppressor

        (1) If engines are consistently low, high or outside the limits defined in the T.O., this is an indication of instrumentation problems, specifically in EPR, P_t6, P_t2 or T_t2.

14. FTIT average on ambient EPR

    a. Test cell/sound suppressor

        (1) Verify that FTIT setting matches T.O. limits for EEC click-setting input.

15. ENP (A_j) ambient EPR

a. Test cell/sound suppressor

(1) Should be less than 20 percent except on hot days (over 80°F) where nozzles may approach 30 percent.

Note: The thrust parameter check is most reliable and repeatable at $T_t2 > 15°C$. Between 5 and 15°C, a region of EPR "saw tooth" can be encountered which may result in poor EPR repeatability. The thrust parameter check is not required below −7°C (0°C for service evaluation program) where the engine normally operates below the FTIT schedule (on the N_2 schedule).

16. Fuel flow limits calculation (if required)

a. Test cell/sound suppressor

(1) Do not trim maximum flow unless you are troubleshooting an A/B squawk. Extensive testing has proven routine adjustments of maximum flow increases the likelihood of A/B problems in flight. There is no objection to checking maximum flow, but adjustments should not be made unless you are troubleshooting for A/B problems.

Recorded values of ± 1,000-1,200 pounds from trim band is within normal repeatability. If the engine has been working properly, and consistent maximum flow levels outside normal repeatability are noted, check instrumentation for errors. If troubleshooting for A/B problems, ensure that the appropriate specific gravity is taken and input to the stand readout. It should be noted that the A/B trim band represents a compromise between operability (high A/B W_f trim causes rumble) and performance (low A/B W_f trim reduces thrust).

17. Present P_b

a. Test cell only

(1) P_b is used during total flow checks and at idle if on minimum P_b. Also an EPR correction is required when P_b is below 250 psia during false EPR point.

(2) It is imperative that P_b be recorded in psia, not psig. This can be accomplished by adding ambient pressure level (14.7 at sea level, less at altitude) to psig gauge reading.

18. Final FTIT

a. Test cell/sound suppressor

(1) Use FTIT recorded during false EPR trim (Item 10).

19. Thrust correction

a. Test cell/sound suppressor

(1) If final false N_2 level (Item 9) is above 12,880 rpm (92 percent), do not add clicks until troubleshooting for RCVV looseness has been accomplished (except 98.5 percent service evaluation which allows one click with N_2 above 12,880 (92 percent) rpm).

(2) If RCVV looseness is found, correct the problem. This will require that the entire trim be re-done, not just ambient EPR.

Do not make a judgement during the false trim that the engine has too high FTIT or will require too many clicks at the ambient point. It is possible for an engine to exhibit high FTIT during false trim and still make acceptable thrust at ambient.

20. Snap accel/decel check

Many activities have asked why additional clicks required from thrust parameter check are not added prior to performing snaps and bodies. This decision was made jointly by the USAF and P&W. The rationale was to reduce engine hot time and cycles. Adding FTIT clicks after snaps and bodies will not adversely affect engine operability. In addition, extensive testing indicates each FTIT click is worth approximately one percent thrust, and the appropriate deltas in EPR values as shown in the T.O.

21. Post-run static checks, similar to those made during pre-run, might also be helpful in isolating instrumentation problems.

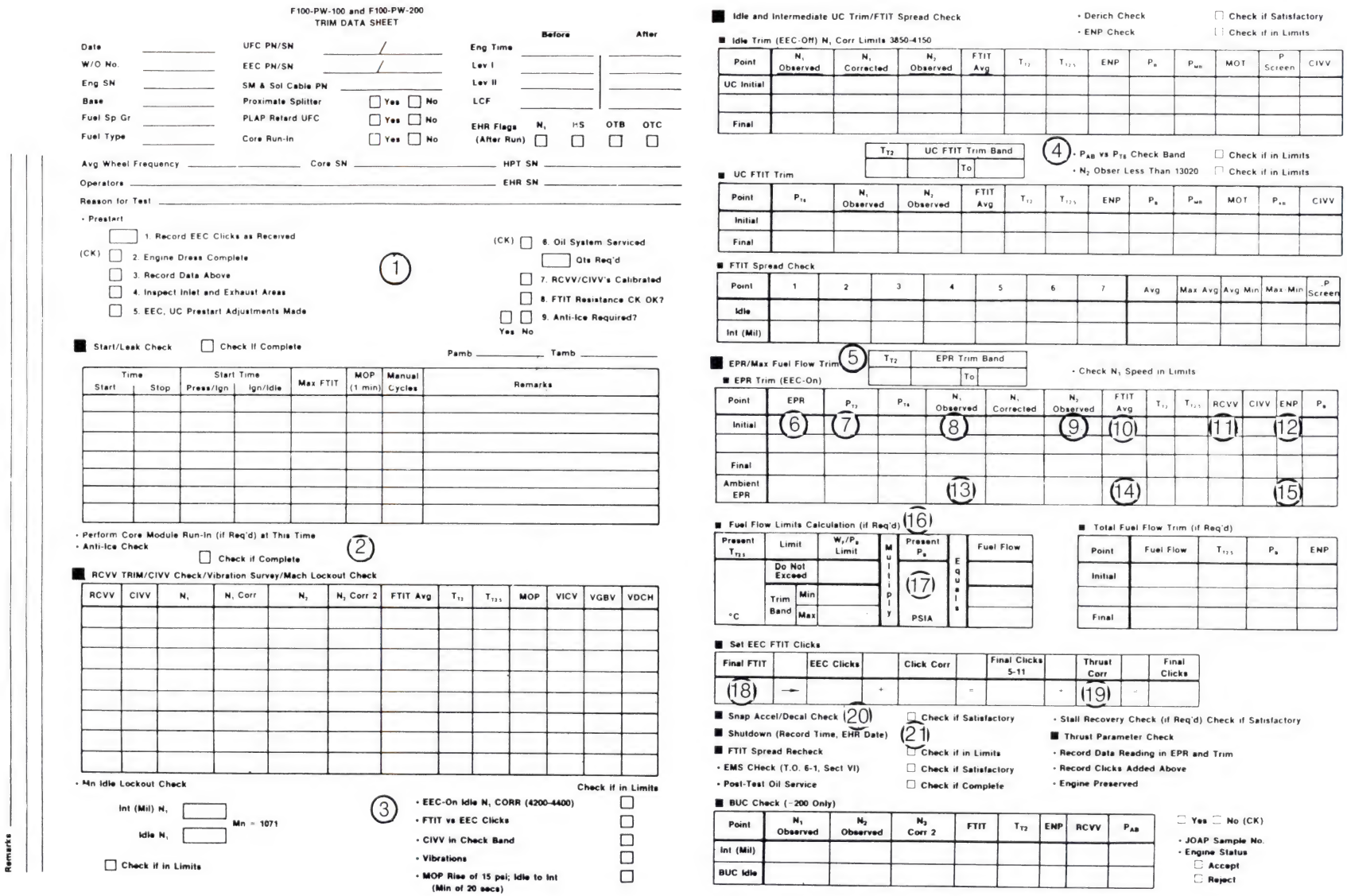


Figure III-16. Trim Sheet (Uninstalled Engine)

Servicing

Section IV

INSTRUCTIONS FOR READING SIGHT GAUGE

Instructions for servicing the engine oil system follow. A schematic of the engine lubrication system is given in Figure IV-1.

Procedure:

Note: Always check oil level within 30 minutes after engine shutdown.

Sight Gauge Area	Action
Level A	Drain to overflow. Check for fuel in oil.
Level B	Do not add oil. Record oil level in test cell log sheet or appropriate aircraft form.
Level C	Add oil. Record oil level in test cell log sheet or appropriate aircraft form.

Caution: If oil level drops more than two graduations for one hour of engine operation, investigate for cause of excess oil consumption. If no oil is visible in the sight gauge, fill it to overflow and troubleshoot for oil consumption.

- Oil level check (30 minutes or more after shutdown). See Figure IV-2.

  1) Fill to Level B-C color break (41-42 half-pints)
  2) Run engine for five minutes at idle
  3) Record level in test cell log sheet or appropriate aircraft form followed by the letter S
  4) Drain or fill to bring level to B-C break line again.

The graduated metal scale mounts over the sight gauge (see TCTO 2J-F100-642). The scale's graduations are in one-half pint increments so the oil tank level can be accurately monitored. Considering that the F100 oil consumption limit is one pint per hour, an oil level drop of more than two increments per hour of engine operation is a reliable signal that the engine is using too much oil. To further help "tip you off" on the status of oil consumption, the sight gauge is colored. There's an upper and lower red zone with a green zone in between. The coloring makes it easy to tell when oil must be added or other corrective action is needed.

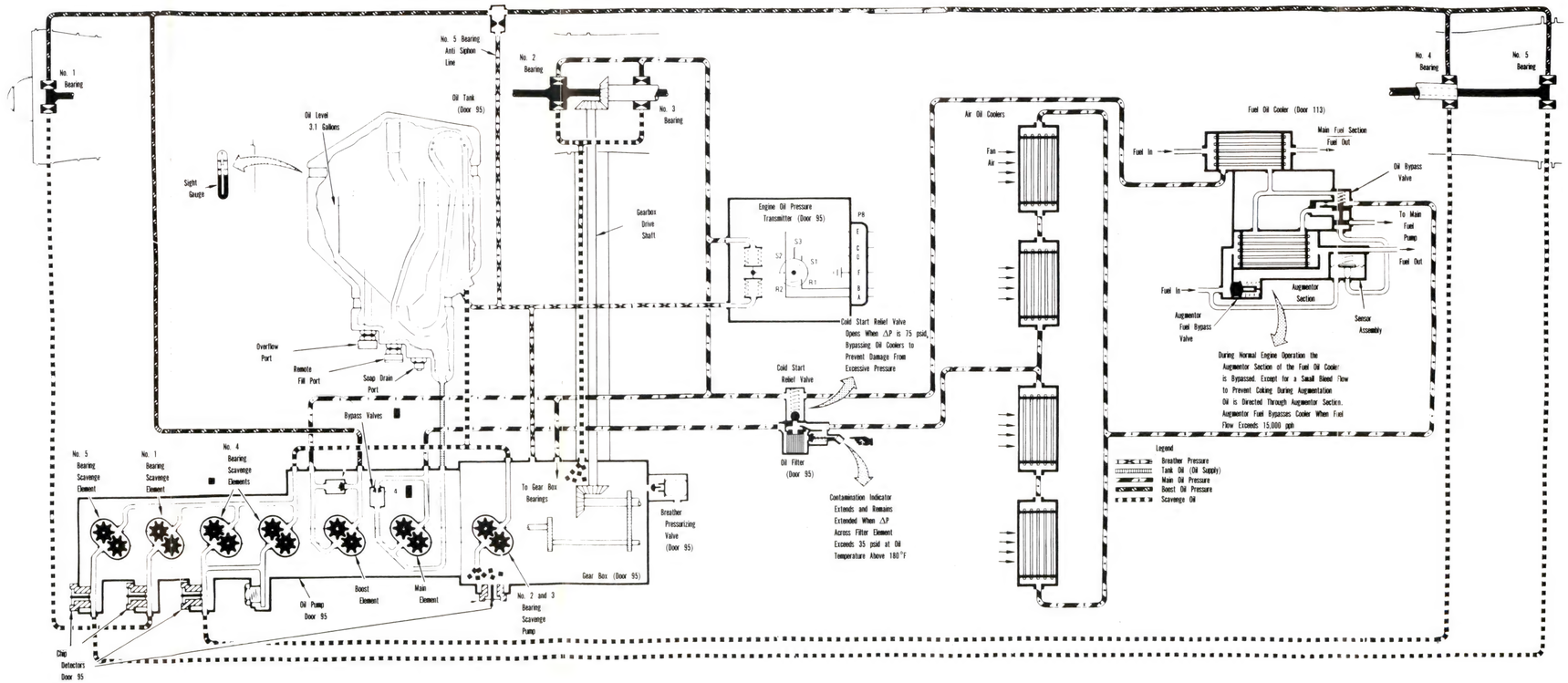

No. 1 Bearing
No. 5 Bearing Anti Siphon Line
No. 2 Bearing
No. 3 Bearing
No. 4 Bearing
No. 5 Bearing
Oil Tank (Door 95)
Oil Level 3.1 Gallons
Sight Gauge
Gearbox Drive Shaft
Engine Oil Pressure Transmitter (Door 95)
Air Oil Coolers
Fan Air
Fuel Oil Cooler (Door 113)
Main Fuel Section
Fuel In
Fuel Out
Oil Bypass Valve
To Main Fuel Pump
Augmentor Section
Augmentor Fuel Bypass Valve
Sensor Assembly
Overflow Port
Remote Fill Port
Soap Drain Port
Bypass Valves
Cold Start Relief Valve Opens When ΔP is 75 psid, Bypassing Oil Coolers to Prevent Damage From Excessive Pressure
Cold Start Relief Valve
Oil Filter (Door 95)
Contamination Indicator Extends and Remains Extended When ΔP Across Filter Element Exceeds 35 psid at Oil Temperature Above 180°F
During Normal Engine Operation the Augmentor Section of the Fuel Oil Cooler is Bypassed, Except for a Small Bleed Flow to Prevent Coking During Augmentation. Oil is Directed Through Augmentor Section. Augmentor Fuel Bypasses Cooler When Fuel Flow Exceeds 15,000 pph
Legend
Breather Pressure
Tank Oil (Oil Supply)
Main Oil Pressure
Boost Oil Pressure
Scavenge Oil
No. 5 Bearing Scavenge Element
No. 1 Bearing Scavenge Element
No. 4 Bearing Scavenge Elements
To Gear Box Bearings
Breather Pressurizing Valve (Door 95)
Gear Box (Door 95)
Oil Pump Door 95
Boost Element
Main Element
No. 2 and 3 Bearing Scavenge Pump
Chip Detectors Door 95

Figure IV-1. Engine Lubrication System Schematic

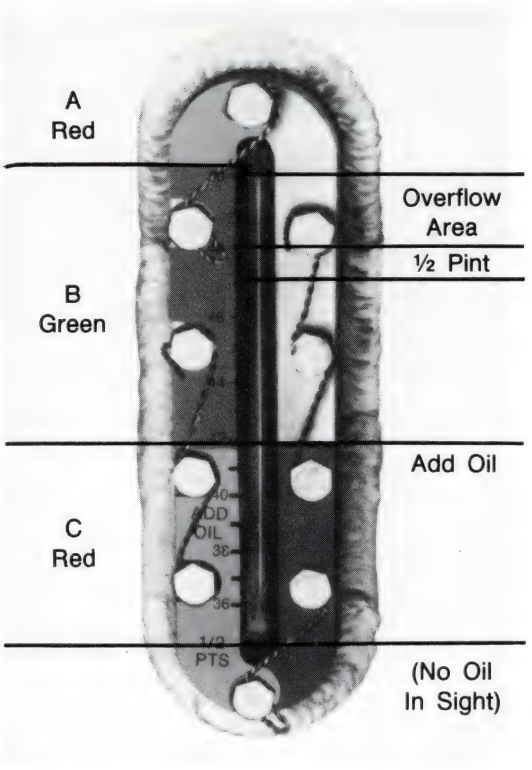


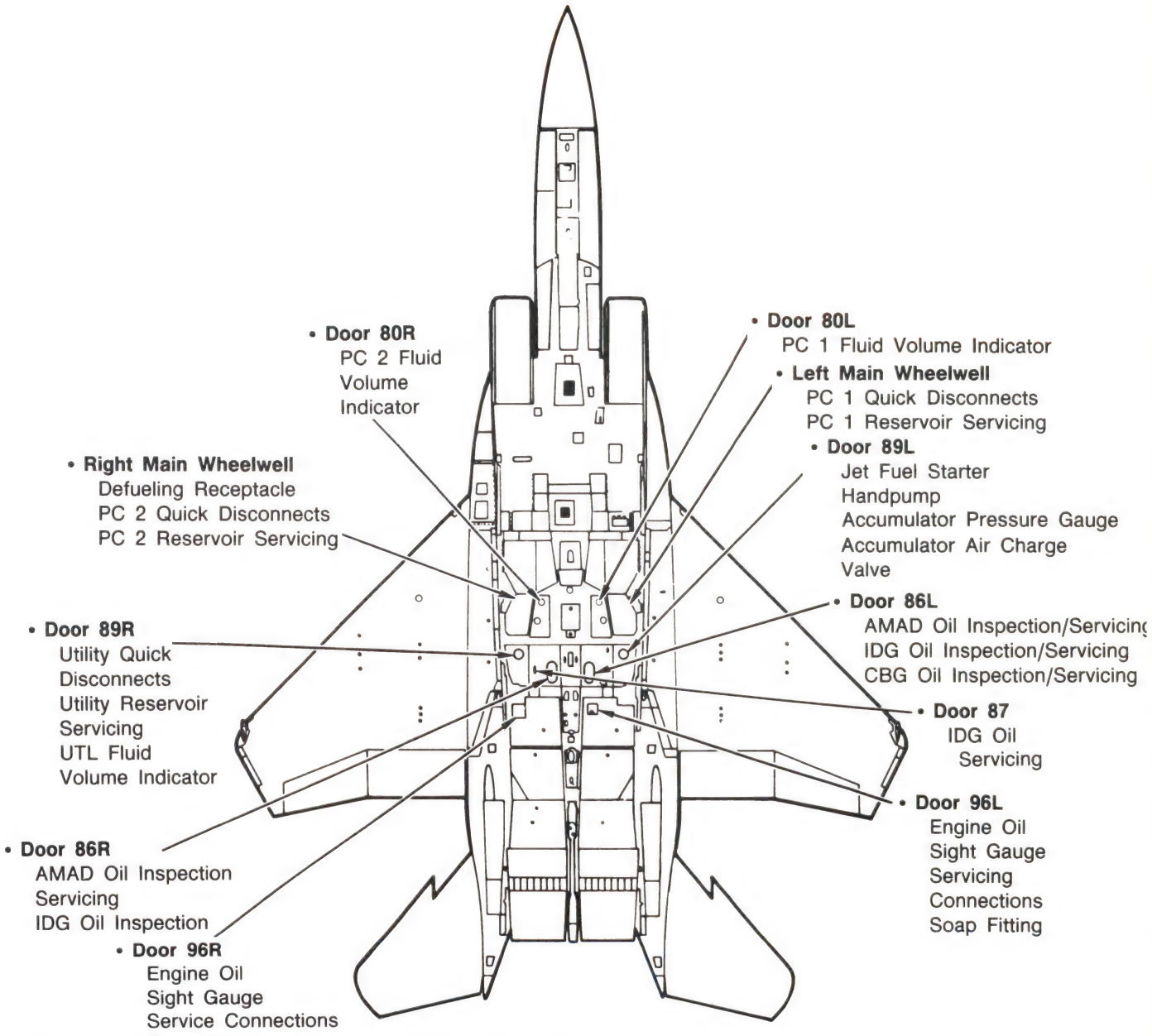
Figure IV-2. Oil Level Sight Gauge

With the sight gauge scale, accurate oil consumption monitoring is possible. Checking engine oil within 30 minutes after every shutdown will make flights safer and will save you maintenance manhours. Best of all, turbine damage, which can result from leaking oil tubes, can be caught before damage occurs.

The red zones indicate corrective action is required. However, oil consumption should be monitored and properly documented in the A/C 781 forms, regardless of what the oil level is (green or red zones).

PROPULSION SYSTEM SERVICING INFORMATION

See Figure IV-3 for servicing component locations and door numbers.



CONSUMABLE	USE	NUMBER
Fuel	F100-PW-100 Engine	MIL-T-5624, JP-4 MIL-T-5624, JP-4 ■ MIL-T-83/33 JP-8
	JFS	

CONSUMABLE	USE	NUMBER
Oil	Engine	MIL-L-7808
	Central Gear Box	
	Integrated Drive Generator	
	AMAD	

Figure IV-3. Propulsion System Servicing Information

Troubleshooting

Section V

TROUBLESHOOTING

Logical thought is the key to successful — and effective — troubleshooting. Think about it! Technicians who have a few years experience with F100 troubleshooting and are familiar with its systems know that fault-isolation ensures each component that can cause a particular problem is tested.

For example, when you get to the last step in the fault-isolation diagram, and it tells you to R/R the UFC, if you've performed each step along the way, you have verified the integrity of all components that could have caused the problem. Of course, that is only if:

1) Your AGE is calibrated and functioning properly.
2) All test connections (electrical and fluid) are clean and tight.
3) All engine connectors (electrical and fluid) are clean and tight.
4) You did not skip any steps.
5) You interpreted the T.O. procedures correctly.

The first four items above are self-explanatory. Item 5 calls for some discussion. The art of troubleshooting high-technology engines is like putting together a jig-saw puzzle. If one piece is missing, the puzzle can't be solved. If one step in the T.O. is missed, your troubleshooting work will be incomplete.

Interpreting tech data correctly is also very important. It's as important as ensuring a tight test connection. Drawing the wrong conclusions when troubleshooting results in several negative consequences. First and foremost is "unconfirmed component removals" (UCRs). When a component is removed and replaced to remedy a squawk, but the unit checks out OK at the depot, this is a UCR. It is then logical to assume that a large sum of USAF budget was wasted. Literally millions of dollars are consumed annually running perfectly good components through the repair cycle. As an example, look at those UCR figures (USAF, F-15 only) during FY 1983. All data is approximate.

Component	Unscheduled R/Rs	% UCR	UCR Cost
UFC	514	27.6	$2,724,700
EEC	899	38	1,064,150
CENC	114	45.6	339,125

The problem may be masked by replacing the wrong component. The problem may re-occur in flight. As an example, let's say you have a dirty electrical connector causing an intermittent problem. The SCS tester registers an "open" circuit. You pull the dirty connector off to OHM-out the harness. It checks OK because you make good multimeter lead-to-connector pin contacts indicating a good harness. This will lead you to believe the electrical circuit within the component is bad. You R/R the component and in doing so re-seat the problem connector. Follow-up SCS electrical checks are now good leading you to believe the component was

the culprit, when in fact all you accomplished was re-seating an electrical connector. This means the component you removed will end up as a UCR statistic.

Flight safety may be compromised here. The dirty connector you re-seated may again cause an intermittent open, and by Murphy's law, will re-occur in flight during the stress and strain of air combat.

Let's look at some actual incidents which resulted from questionable troubleshooting in the F100 world. Test yourself. First, read the squawk. Then, before reading the discussion, try to determine what could cause the problem, and/or what action(s) may have prevented the incident.

Squawk: Stall/stagnation at MAX power/33K/210 kts (fourth occurrence). Good airstart made. Troubleshooting found loose RCVVs which could not be trimmed into the band, bad N_2 sensor and aircraft Mn signal to EEC.

> Discussion: Why weren't RCVVs checked for looseness while troubleshooting the first three occurrences? Were the bad N_2 sensor and Mn signal contributors to the previous three stalls? Maybe! But it's unlikely that both units failed during the fourth flight, if at all.

Squawk: Single-engine landing due to low oil pressure (5 psi). Troubleshooting revealed air/oil cooler oil-out line chaffed through by RCVV fuel line.

> Discussion: No discussion necessary. If tech data is adhered to, chaffing cannot occur.

Squawk: Stall/stagnation at MIL/17K/350 kts. Good airstart made. Troubleshooting found bad stator generator and found the AP4 borescope guide tube (what was left of it) still installed in the combustor. The engine was removed for metal splatter in the HPT.

> Discussion: Since there was no mention of an overtemp, the squawk could have been cleared by a generator swap. But, borescope inspection procedures in the tech data were not complied with, resulting in an expensive UER and teardown to the HPT.

Squawk: A/B blowout on takeoff and no-light in flight. Troubleshooting found 13th-stage bleed air clamp missing from the augmentor fuel pump with the bleed air line separated from the pump. RCVV's stuck full axial, therefore, the core was removed due to a possibility of HPC blade flutter/fatigue.

> Discussion: If the T.O. had been followed (re-install clamp) the problem would not have occurred and the core wouldn't have to undergo an expensive depot teardown for compressor blade fatigue testing.

Squawk: Stall/stagnation at Max power/27K/250 kts. Good airstart made. Troubleshooting found RCVV misrigged 1/8 inch, left RCVV bellcrank with 0.100 inch wear, and badly worn RCVV cylinder bracket and bolt.

Discussion: RCVV looseness (wear) is the major contributor to current performance problems, even when the vanes are properly rigged.

Squawk: Flight abort for fluxing oil pressure (10-80 psi). Found dirty cannon plug on oil pressure transmitter. The plug was cleaned and the problem cleared.

Discussion: All the connectors in the engine bay are subject to this problem due to residual fuel and oil being blown around by bay cooling air flow. Make a habit of cleaning all electrical connectors prior to installation. Use the proper fluids per tech data. Don't use WD-40! It has an oil base and will only aggravate the conditions. Also, don't replace electrical components until you've duplicated the problem with clean connectors.

As mentioned earlier, effective interpretation of tech data is imperative. Most T.O. procedures are easy to understand, yet, there are many documented cases of misinterpretation which resulted in incidents or even crashes. Want to see how it happens? Let's play a game. Follow the instructions below. No fair cheating!

How good are your interpretive skills?

Read this sentence:

FINISHED FILES ARE THE RESULT OF YEARS OF SCIENTIFIC STUDY COMBINED WITH THE EXPERIENCE OF YEARS.

Now, count aloud the F's. Count them only once. Do not go back and count them again.

How many F's did you count? There's no trick to this. There are six. Few people get it right the first time, because you can't scan or speed read and effectively absorb all data. Speed reading technical directions or the many numeric values in the T.O. can lead to disaster. Read tech data thoroughly. You can't be too careful.

Please remember that the fault-isolation diagrams are a compilation of information specifically designed to eliminate malfunctioning components, both through logical deduction and operational history. Those of you new to state-of-the-art machinery should follow tech data to the letter. Those of you with experience know that working from memory is a sure-fire preface to disaster. Few, if any, maintenance procedures remain unchanged throughout the life-cycle of a high-technology machine.

Don't forget, when you find an error in tech data or you find a better way to do a job, fill out an AFTO 22. Contact your Pratt & Whitney representative. He'll be glad to assist you in formulating such documentation.

HUNG START

The engine must provide the torque necessary to accelerate above JFS motoring speed (Figure V-1). The engine normally accelerates from light-off to 50 percent N_2 in about 15 seconds. If for any reason the fuel flow is abnormally low, the first thing you will notice is slow acceleration. The time required to get to 50 percent N_2 may be twice the normal time, or even longer. Just after the JFS disengages, engine rpm acceleration rate will decrease. This usually occurs in the 45-52 percent speed range and is due to an increase in torque required as the main generator comes on line and the JFS disengages.

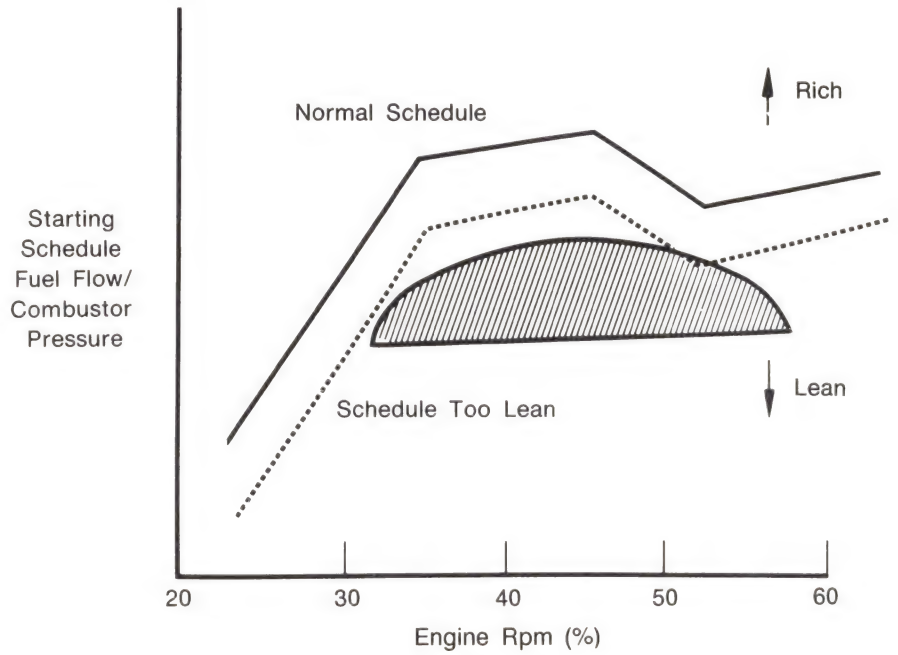


Figure V-1. Hung Start

More fuel flow is needed to overcome a hung start. If you move the derich switch to "high" you will get about 100 pph more fuel and the engine should accelerate to idle. If it takes any more than five seconds of increased fuel flow to get to idle, then the fuel flow is unacceptably low or some other deficiency has caused excessive torque loads. In this event the start should be discontinued to troubleshoot the discrepancy. Hung starts sometimes go hot when "high" is selected, so closely monitor FTIT during a hung start.

Enriching a hung start on the M37 test cell is not allowed. Troubleshoot the problem to identify a cause.

One of the signals necessary for the UC to properly schedule start fuel flow is P_b. Hung starts will occur if moisture/condensation collects and freezes within the P_b line, blocking the P_b signal to the UC. The P_b drain must be removed to drain condensation from the UC P_b cavity. A TCTO will be

issued to incorporate a continuous flow orifice for the UC. This new assembly will allow condensation to drain overboard from the P_b system as it forms. Meanwhile, be sure the UC is receiving a good P_b input by confirming the line is not plugged by foreign matter.

HOT START

Hot starts are caused by: (1) start fuel flow too rich (a depot level adjustment), (2) starting stall margin too low (compressor abradable wear), (3) a bleed strap malfunction or (4) JFS deficiency (Figure V-2).

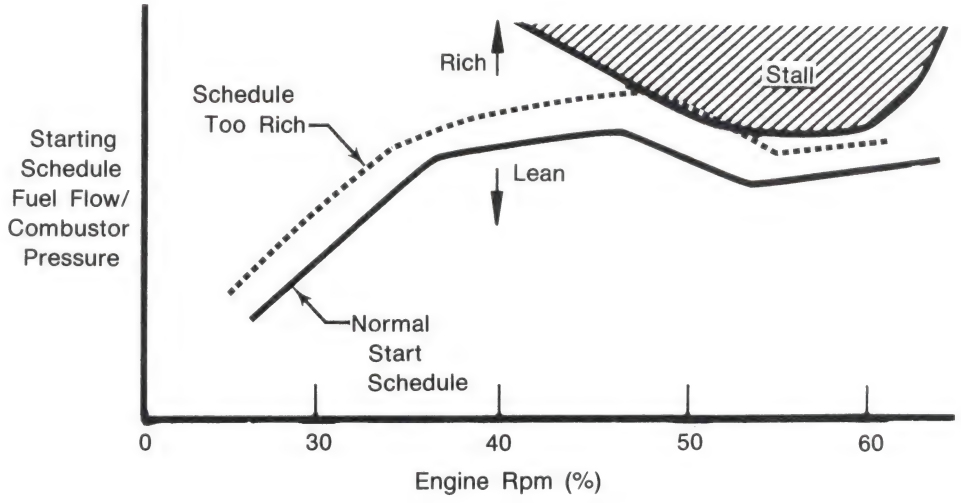


Figure V-2. Hot Start

Condition 1, an infrequent occurrence, can only be corrected by returning the UC to depot.

In condition 2, if the aircraft auto derich system doesn't derich during the start cycle, put the switch to the "low" position. If it corrects the problem, troubleshoot the aircraft auto derich system. If it does not, troubleshoot the engine to determine the cause of the hot starts.

In condition 3, if the start bleed does not function as designed during starting, the high compressor may stall. Troubleshoot the bleed strap malfunction.

What does the air source selection do for you? The engine may have hot-started because it has either lost some stall margin in the below-idle range or because the start-fuel schedule has shifted to a slightly over-rich condition. Selecting to bleed from the engine being started has the effect of increasing stall margin, i.e., moves the stall region away from the start schedule. There is no means of lowering the fuel scheduled any further, because the "auto" position of the derich switch automatically gives you

low (deriched) fuel flow until 30 seconds after the main generator comes on line. Therefore, the derich switch cannot help you in this situation unless the "auto" function is inoperative.

If FTIT has not exceeded the starting limit of 680°C, a second attempt is recommended and should be successful with bleed selected to the engine being started. More than two attempts are not recommended.

EEC LIGHT

The cockpit EEC light (Figure V-3) will illuminate for one of three reasons: (1) EEC failure, (2) EEC input failure from the engine or aircraft, (3) detection of a fan overspeed.

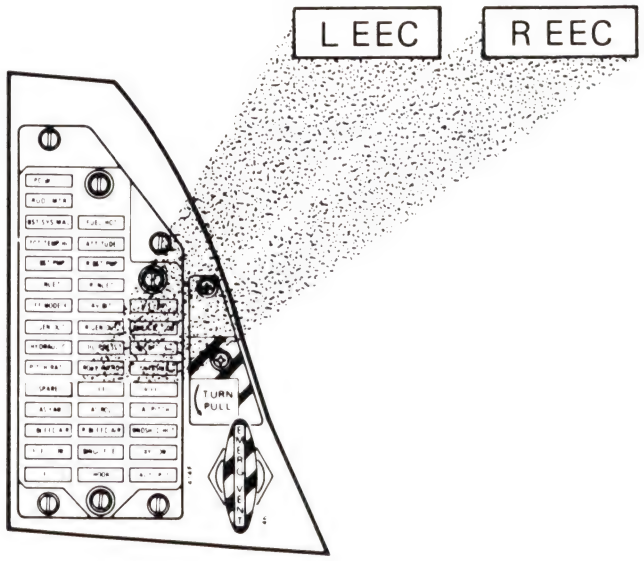


Figure V-3. EEC Light

The EEC's fault detection logic permits it to detect approximately half of its possible failure modes. Since the EEC cannot detect all internal failures, the absence of an EEC light does not preclude the possibility of an EEC malfunction.

If the EEC were to lose a critical input from another engine component, such as the T_t2 sensor, N_1sensor or FTIT probes, it would go into a fail-safe operating mode and illuminate the EEC light. The same holds true for loss of a critical aircraft input: Mach number. The lack of a Mach number signal causes the EEC to operate in a fail-safe mode and illuminate the EEC light. An electrical power interrupt in the aircraft can also cause a momentary loss of Mach number input to the EEC and an EEC light. If the ODU senses a fan overspeed, it will turn the EEC off and illuminate the EEC light.

Cycling the EEC on-off-on with the troubled engine at idle will clear the problem if it was a result of a momentary malfunction of the EEC or one of its inputs. If the light does not clear, it is evidence of an EEC or EEC input failure or a fan overspeed.

A/B No-Light and Blowout

The following problems can cause a no-light or blowout:

A/B wash filter — If the wash filter is clogged, no-lights will occur. Be sure to check wash filter ΔP.

A/B ignition system fault — If a fault develops with the afterburner ignition system, which includes the UC, engine stator generator, exciters, igniters, cables and flameholder, then no-lights can result.

Misscheduled engine compressor geometry — RCVVs, when misscheduled in the cambered direction, can increase the probability of no-lights and blowouts.

Low engine pressure ratio — When the engine is schedule at too low an EPR due to a control malfunction or mistrim, the result can be no-lights, blowouts or rumble.

Improper nozzle response — Sluggish or "sticky" nozzle response may result in a too large nozzle area during A/B transients and cause no-lights or blowouts.

Misscheduled A/B fuel flow — A/B fuel flow, which is either too rich or too lean due to mistrim or a control malfunction, can result in no-lights or blowouts.

High altitude/low airspeed — As you climb in altitude the density and pressure of burnable air decreases, therefore pressure and air density drops in the A/B. As aircraft velocity drops so does ram pressure of the air delivered to the engine face. This combination, or flying into the "upper left-hand corner of the envelope," results in lower pressure and density of the air delivered to the engine at a reduced ram velocity. No-lights and blowouts may occur because the fuel-to-air ratio is becoming too rich (see A/B operating envelope, page 84).

How to Recognize a No-Light or Blowout

While you are troubleshooting or trimming the engine, you can recognize a no-light because the nozzle will open to a little over 30 percent and close back down as shown in Figure V-4. If a blowout occurs the nozzle may reach its normal maximum A/B position of approximately 75 percent and then close, or it may begin to close before 75 percent nozzle is reached if the blowout occurs in one of the early segments of A/B.

In the cases of no-lights and blowouts, you never hear a "bang." The bang is a stall which may have occurred because of a relight after the initial no-

light or blowout. If the no-light or blowout is not recognized and the throttle is not quickly reduced to MIL power or below, an auto-ignition stall may occur.

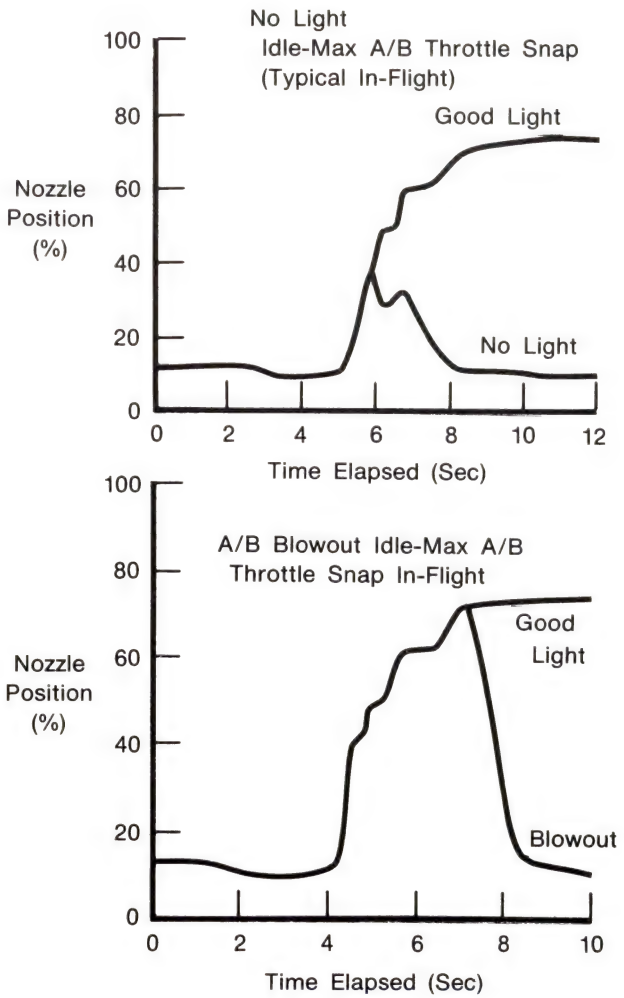


Figure V-4. No-Light Blowout Indications

Closely monitor nozzle position when you initiate A/B. The initial movement of the nozzle is not as important as how it continues to open at mid-range A/B. When reaching the 30-50 percent range, you should be concerned if the nozzle sequencing slows, stops or reverses. This indicates the A/B is not lighting and the nozzle is closing to control fan speed (N_1). If the throttle is still at max, fuel will continue to be pumped into the A/B. This massive amount of raw fuel will be ignited by the hot gases exiting the turbine which can create an "explosive" situation. This is an auto-ignition and will result in a fireball out the tailpipe and the inlet. In this instance, a severe engine stall is probable.

A/B No-Light and Blowout on Takeoff

It is often difficult for the pilot to differentiate between a no-light and a blowout during takeoff. Extensive test data indicate the possibility of a blowout on the ground is very remote. These occurrences are believed to be improper (or partial) light-offs or autolights resulting in a fan stall and A/B blowout. This all happens so quickly that it can fool the pilot into perceiving it as a normal light-off followed by an immediate blowout at A/B initiation. No only that, he writes up what he feels, not what he sees because his eyes are "out of the cockpit" during takeoff, especially if it's a formation takeoff. We know that A/B takeoff problems are reported by the pilots as 70 percent no-lights and 30 percent blowouts and that 75 percent of corrective actions are signed off as CND or a minor trim adjustment.

Many parameters can affect A/B light-off as apparent in the respective fault tree. Some of the tests you perform in the fault tree that are critically important are:

- Flameholder gap (physical measurement)
- Segment 1 light-off ratios (trim)
- UC wash filter ΔP check
- A/B ignition system integrity (visual and operational)
- TCTO 2J-F100-624 compliance (increased Segment 1 orifice).

Pratt & Whitney and the USAF have undertaken investigations at bases that experience unusually high rates of A/B takeoff squawks. These efforts include intensive pilot debrief, squawk analysis and preventive maintenance checks during phase inspections.

If you have information that may alleviate the A/B no-light problem, please bring it to the attention of your shop supervision and your P&W representative.

A/B OPERATING ENVELOPE

The A/B operating envelope is divided into three areas based on the probability of afterburner transient success (Figure V-5). These areas were determined through instrumented flight testing and operational F-15 experience. They aid us in troubleshooting. For instance, if stalls occur in Region 1, there is often a component malfunction. The regions and their characteristics are described below.

Region 1 — unrestricted afterburner operation. Mislights, blowouts or stalls should not occur. Some afterburner rumble may occur.

Region 2 — most afterburner transients successful. Afterburner mislights, light-off stalls or rumble-associated blowouts or stalls may occur during throttle transients into afterburner, but should not occur during steady-state afterburner operation.

Region 3 — steady-state afterburner operation or afterburner cancellations only. Afterburner mislights, light-off stalls, blowouts and rumble-associated stalls are probable during transients from all power settings. Afterburner rumble and blowouts are possible during steady-state operation.

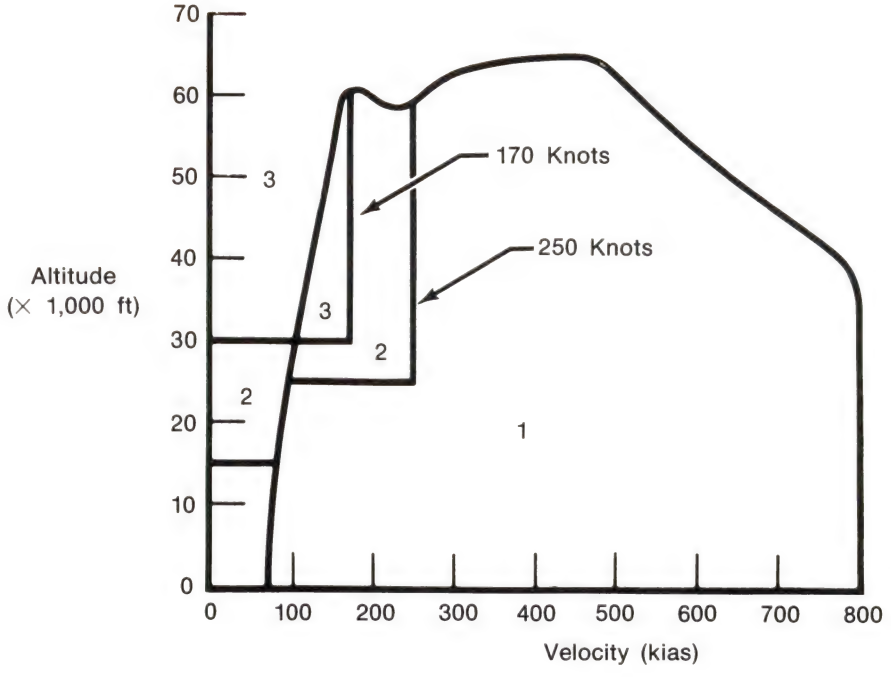


Figure V-5. A/B Operating Envelope

SEGMENT 5 LOCKOUT IMPROVES ULHC A/B OPERATION

Segment 5 of the A/B is locked out (shut off) at higher altitudes and lower airspeeds to improve A/B transient success by "leaning out" the fuel-to-air ratio. As the aircraft climbs and/or decelerates into the Segment 5 lockout region, the pilot feels some thrust loss and sees a 10-15 percent reduction of nozzle area and a corresponding drop in fuel flow. He will see the same in reverse as he flies out of this region (Figure V-6).

The engine control system locks out Segment 5 as a function of P_b and T_t2. The line shown in Figure V-7 is a nominal line which will vary as a function of T_t2 engine trim and individual engine performance. Because of these variables, the line shown can vary by approximately 0.2 Mn.

OIL CONSUMPTION

When the low oil pressure caution light illuminates due to low engine oil pressure (Figure V-7), the engine has already lost approximately 75 percent of its usable oil. Two clues to an earlier indication of oil loss are: (1) no oil pressure increase from the idle to MIL power, and (2) oil pressure at any throttle setting dropping 5 psi below idle oil pressure levels.

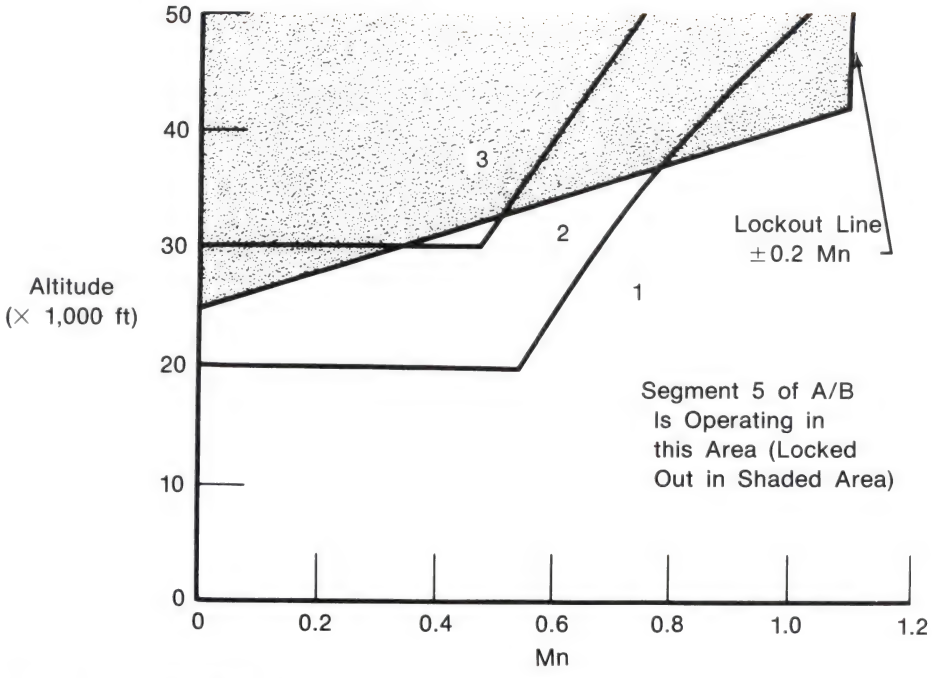


Figure V-6. Segment 5 Lockout

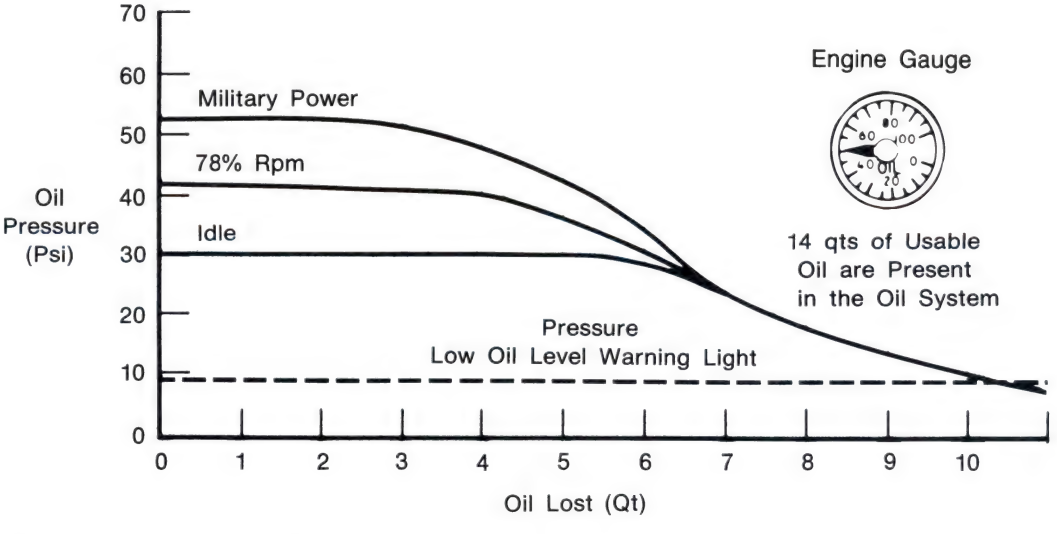


Figure V-7. Oil Level Warning

If the oil pressure light comes on, the oil pressure is below 8 psi. If this occurs, immediately discontinue the run and troubleshoot the oil system. Running without oil can cause failures dangerous to the engine and aircraft, not to mention your ground crew.

For example, an F-15 engine intermittently consumed excessive oil (14 1/2 pints on one sortie; 15 1/2 pints on the second sortie) over several weeks. Although installed consumption runs could not duplicate the problem, the engine continued to sporadically consume excessive oil.

This kind of chronic consumption carries serious implications and should be dealt with in the engine shop (bearing cavity vacuum checks, etc.) and on the test cell for intensive investigation.

As it turned out, this engine was losing oil from the No. 4 bearing area, which resulted in a turbine bore fire. The burning oil distressed the second-stage turbine wheel until it finally fractured in flight and seized the rotor. The wheel fragments were luckily contained by the turbine case, and the aircraft made it home on the other engine.

Please don't forget that excessive oil consumption, without an obvious external leak, may result in a severe inflight failure.

NO THROTTLE RESPONSE

A failure of the N_2 sensor that supplies the rpm signal to the UC causes the engine to go to a fail-safe position. This results in: lack of throttle response, rpm at or near normal military power levels and FTIT low in relationship to rpm.

This abnormal situation is caused by the rear compressor variable vanes (RCVV) moving to a mid-range (fail-safe) position. Usually the engine can be shut down by moving the throttle to cutoff.

If for any reason the engine won't shut down with the throttle, you'll have to move the engine master switch to off. This will starve the engine of fuel by closing the main fuel shutoff valve.

STALL

The stall is one of the most talked about, yet least understood, problems with an afterburning jet engine.

The reason for a stall is that air flowing across the fan or compressor blades is momentarily disrupted. The causes are wide-ranging, from control system malfunctions to violent aircraft maneuvers distorting the inlet air flow to pressures in the tailpipe backing up through the fan duct to the compressors.

The stalls resulting from violent maneuvering or flying through a jet wash can't be helped. But when the pilot can't relate the stall to a non-engine problem, technicians have to go to work. You must look to the engine hardware that's pumping the air and the components that control them for a cause.

Types of Stalls

The majority of stalls are A/B related. An A/B disturbance, like a hard light, a sequencing problem or fuel scheduling, creates a pressure pulse that travels forward up the fan duct and back pressures the fan (Figure V-8). The fan then stalls and sometimes causes the high compressor (core engine) to stall if the nozzle can't react fast enough to open up and dump the excess pressure. This type of stall is referred to as augmentor induced. There is a fault tree dedicated to this occurrence. This type of stall often results in a "CND" or "retrimmed and released" sign-off.

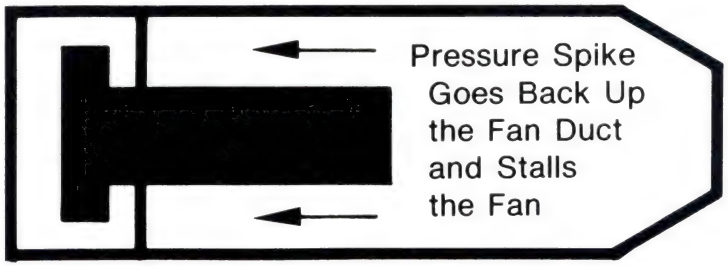


Figure V-8. Pressure Spike

A second type of stall occurs from part power to MIL. This seldom happens, and when it does you will usually find a malfunctioning component or that the engine is out of trim. The RCVV's can cause this if they are off schedule or when RCVV hardware is worn.

The third type of stall is the off-idle stall. Idle trim out of limits or a component malfunction is usually the cause.

Mechanics of a Stall

A stall happens so quickly that the disruption (or reversal) of airflow only lasts for about 1/10 second, or less. In many instances this momentary disruption will clear itself because: (1) the control system is opening the nozzle to try to dump the A/B-induced pressure spike so the engine can recover, and (2) the rotors don't stop or reverse direction during the stall, so normal airflow can be restored because the compressor is still pumping air rearward. This is a recoverable stall.

If neither of these efforts are successful and normal airflow cannot be restored, you have a nonrecoverable stall. The F100 term for this is stagnation.

If airflow is not quickly restored, numerous 1/10-second stalls can occur back-to-back. These reversals of airflow absorb energy from the rotating hardware (the fan and/or compressor) and cause them to slow down (rpm drops).

The throttle (if it hasn't been retarded) is now requesting more fuel than the reduced airflow can handle. So, while rpm, and therefore airflow, is going down, FTIT is climbing. This is a dangerous situation because now there isn't sufficient airflow to support combustion in the combustor or cool the turbine. So the burning process occurs in the turbine, which will result in an overtemp and possible turbine distress. Under these conditions (rpm dropping and FTIT climbing), you will also find that you have no response to throttle movements. A stagnation has occurred.

In many cases if you experience a stall while running the engine, quick and appropriate reaction on your part can catch the stall or prevent a stagnation.

Reacting to Stalls

At low power (idle or part power) the stall may be inaudible, and you may not know it has happened until you can't get a response to throttle movement or you notice the FTIT needle wringing itself off of the gauge while rpm has spooled down below 60 percent. With no chance to recover from this, you should snap the throttle to cut-off and fire up the JFS so you can immediately motor the engine to cool the overtemping turbine.

If the stall occurs at a higher part-power setting (not A/B), it is more likely to be audible. The sounds are usually described as "pops," "bangs," "thuds," or may even send a tremor through the aircraft. As long as FTIT is not approaching the limits (check the T.O.), snap the throttle to idle. It will probably recover. If FTIT hangs up within limits, the rpm may begin to spool up for recover. If rpm goes below 60 percent, shut down and be ready to crank the JFS if overtemp occurs.

Reacting to Stagnations

If you survived the stall by reacting appropriately, but the engine stagnates, remember, a stagnation is a stall that didn't recover. There is no fault diagram dedicated to the stagnation alone because it is the result of a stall.

Cockpit indications must be monitored carefully now because stagnations on the ground almost always result in an overtemp. Figures V-9 and V-10 show how rpm and FTIT will react during a stagnation. The information was taken from inflight readings, but it will give you some idea of what to expect.

FTIT and rpm response during a low-power stagnation

During a low-power stagnation, FTIT increases while rpm decreases in a manner similar to that shown in Figure V-9. The rate at which FTIT increases and rpm decreases can vary.

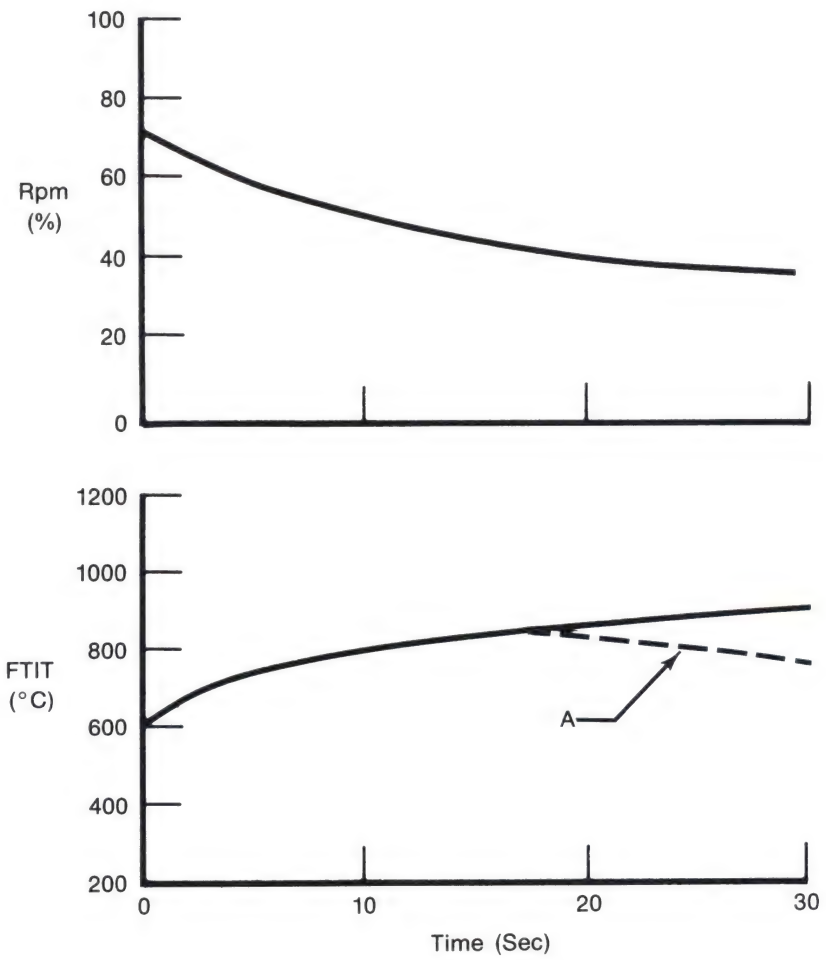


Figure V-9. FTIT and Rpm Response During a Low-Power Stagnation

FTIT following a low power stagnation will often level off at 800 to 1000°C. Occasionally it may even begin to decrease slowly if the engine is left in stagnation for several seconds as shown in Case A. The rpm drops off at the same rate regardless of FTIT response because the engine is still in stagnation. However, an overtemp may occur.

When an inflight stagnation occurs, the pilot has ram air that cools the engine after shutdown. Obviously you don't have ram air on the ground. So, be familiar with the procedures for motoring to cool a stagnated (or overtemping) engine.

FTIT and rpm response during a high-power stagnation

During a high-power stagnation, FTIT increases while rpm decreases in a manner similar to that shown in Figure V-10. The rate at which FTIT increases and rpm decreases can vary.

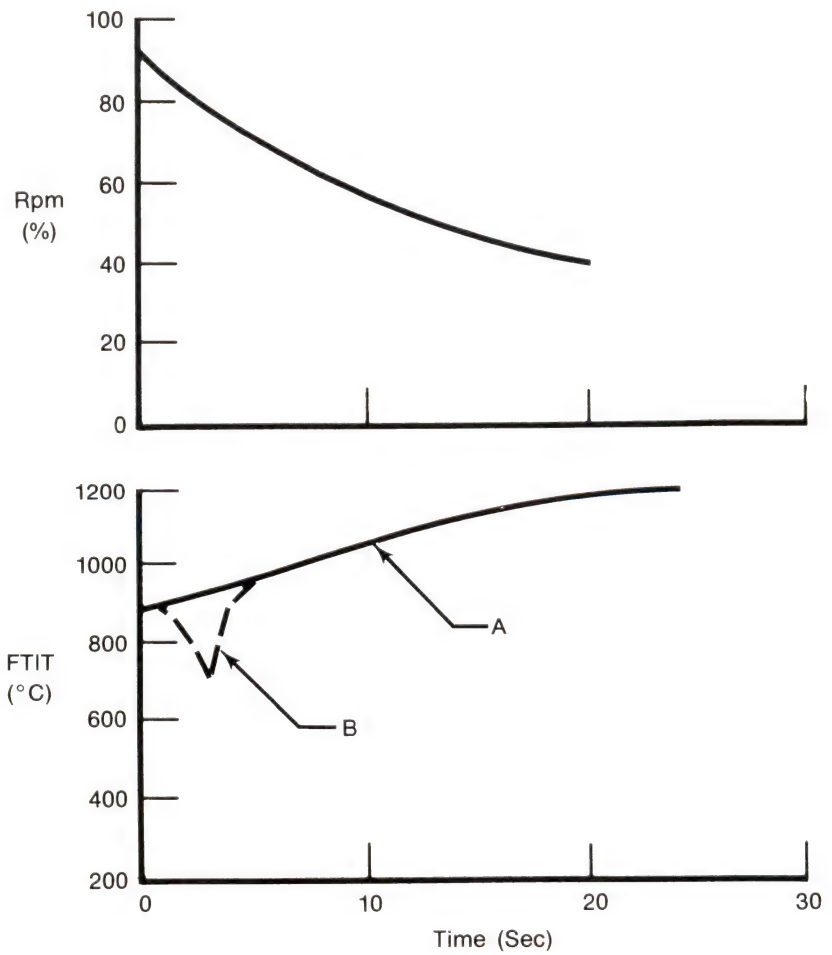


Figure V-10. FTIT and Rpm Response During a High-Power Stagnation

The rpm signature always looks similar, but the rate of decay varies. On the ground, rpm decays much more rapidly than in flight. So you have even less time to react than the pilot does.

The FTIT signature varies within the initial few seconds after high-power stagnation, as shown by the two cases in Figure V-10. Case A shows typical rapid increase in FTIT and rapidly decreasing rpm. Case B shows an immediate drop in FTIT of up to 200°C as a result of a momentary main combustor blowout. Re-ignition always occurs within a few seconds causing FTIT to rise rapidly. Again, rpm decreases rapidly. Case B is an unlikely occurrence on the ground.

The operator should be aware that the cases shown are typical traces of FTIT. Occasionally, FTIT will spike up very rapidly and keep going up. When this happens, be ready to shut down, crank the JFS and motor the engine to cool it down.

If you encounter a stall or stagnation, remember the following:

- Monitor FTIT. If it is going hot, shut down and be ready to motor the engine with the JFS. Don't get over-anxious and "crash engage" the JFS when N_2 is still above 30 percent. CGB drive train damage will result.

- React swiftly. You have less time to react than the pilot does because you have no ram air to help clear the stall or cool down a stagnated engine.

- If an overtemp occurs, make a mental note of the highest FTIT you see and how many seconds temperature limits were exceeded. There are different levels of overtemp requiring different corrective actions based on "time at overtemp." It is better to over-inspect an overtemped engine than to under-inspect a damaged engine.

- If rpm drops below 60 percent (for any reason) shut down immediately. There is no chance to recover normal operation in this instance. Again, watch your FTIT.

- If you've had to shut down from A/B and you have a tailpipe fire:
  — If the fire is contained in the tailpipe, only motoring with JFS will help (blowing the on-board fire bottle won't help — it's for fires external to the engine).
  — Don't blow ground fire extinguisher chemicals up the tailpipe unless you can't motor the engine for some reason (JFS inoperative), there is more fire than the JFS can blow out, or burning fuel is spilling out of the tailpipe (unlikely event).

When in doubt, shut down and closely monitor FTIT.

Maintenance Tips

Section VI

POTENTIAL FOD

Incidents of FOD have occurred when the PN 525211 bolt (head) broke off, fell out of the inlet cone and entered the gaspath. These bolts attached the inlet cone support to the inlet case (Figure VI-1). They were overtorqued.

Be doubly careful to follow the T.O. data when assembling and torquing components that are directly in the gaspath or inlet areas. These parts have no place to go, but down the inlet should they come "unglued" during engine operation.

So, be aware that loose parts and fan blades don't mix.

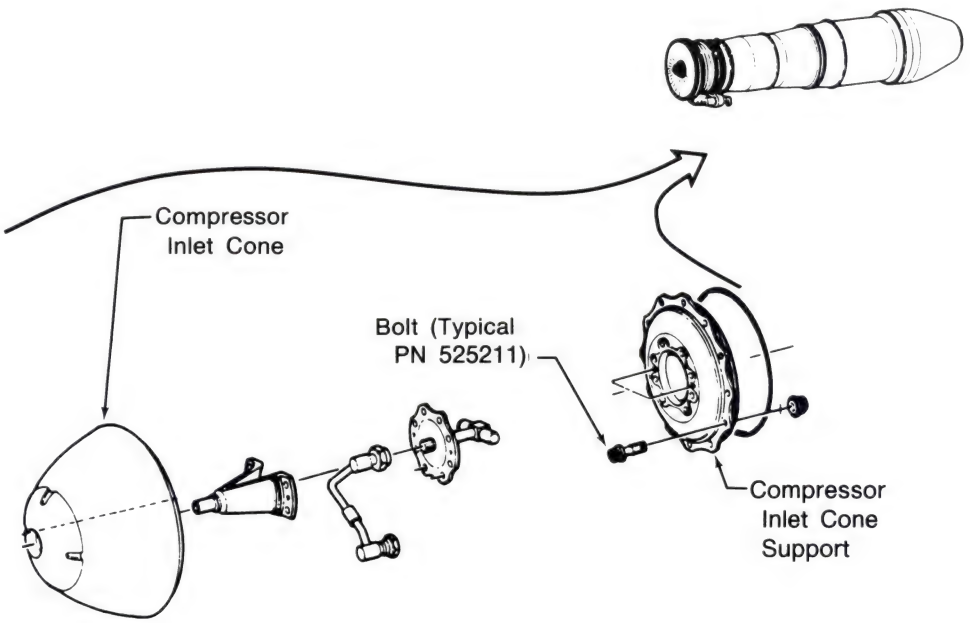


Figure VI-1. Proper Assembly of Compressor Inlet Cone

FUEL AND OIL LEAKS/PLUMBING

Plumbing problems continue on a fleet-wide basis. Fuel and oil leaks caused by tube chafing, cracking and various other leak-causing discrepancies, have resulted in an unacceptable rate of inflight emergencies. Contamination in fuel and oil systems can get there if plumbing lines or components are not properly plugged/capped during maintenance.

Look for:

- Proper plumbing line clearances
- Bent tubes
- Damaged tubes (nicks, dings, tool marks, etc.)
- Conical seal installation
- Properly positioned and secured clamps
- Proper safety wiring
- Uncapped ports or lines.

The T.O. says it all. Be sure seals, fittings, torques, clearances and safety wiring are by the book. A massive fuel or oil leak in the engine bay endangers maintenance personnel, pilots, the aircraft and the mission.

A videotape is available on this subject from your P&W representative.

CRITICAL ELECTRICAL CONNECTIONS

Generator connectors P20 (EEC power and cockpit rpm signal) and P21 (engine ignition) have decoupled during engine operation and in flight. When P20 disconnects, the pilot loses rpm indication and the EEC is depowered. When P21 disconnects, the engine can't start, or more importantly, can't air start due to loss of ignition.

Failure to adequately secure these connectors (Figure VI-2) prior to safety wiring or clamping results in vibratory-induced wear and connector decoupling (the snap ring that holds the coupling nut onto the backshell wears through).

After installing these connectors (as well as all others), confirm bottoming of the connector by applying pressure to the backshell. You should also try to shake the backshell. No relative motion should occur between it and the knurled connector ring. Checking the "red ring" does not ensure a proper connection. Only a hands-on check will identify a worn snap ring.

A videotape on this subject is available from your P&W representative.

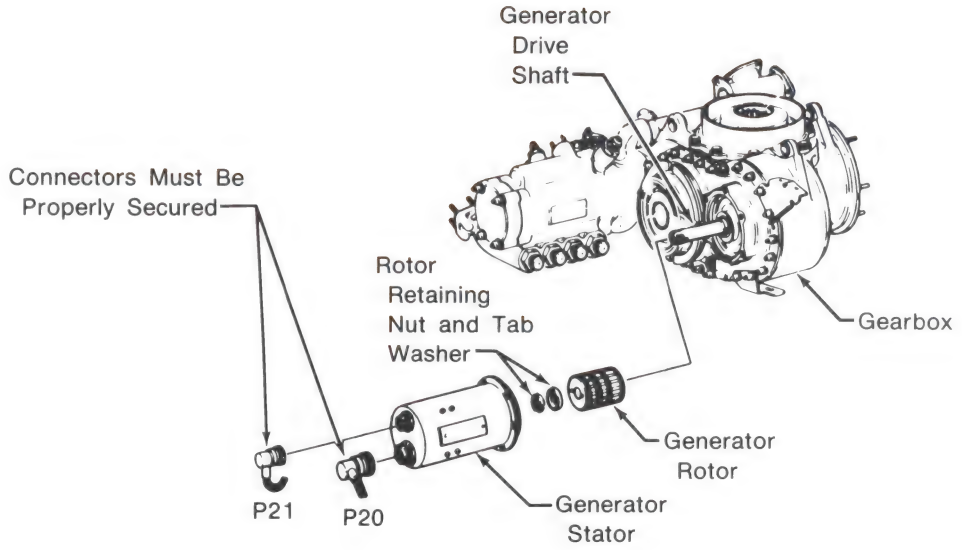


Figure VI-2. Critical Electrical Connections

FOURTH-STAGE TURBINE AIRSEAL BOLTS

Fourth-stage turbine airseal bolts have backed out and entered the gaspath, resulting in damage to the trailing edge of the fourth-stage turbine blades. This can cause damage from minor nicks to turbine blade fracture and result in massive turbine damage.

During tailpipe inspection or when the engine enters JEIM, inspect fourth-turbine blade trailing edges and tip shrouds (Figure VI-3) for damage. It's an easy check that may avert a serious mishap. Several turbines were sent to depot with fourth-blade trailing edge damage. Cracks were found propogating from some of the "dings," which could have led to blade fracture.

TCTO 2J-F100 III-511 has improved bolt retention. But remember that only your educated eye can detect the damage caused by a missing bolt.

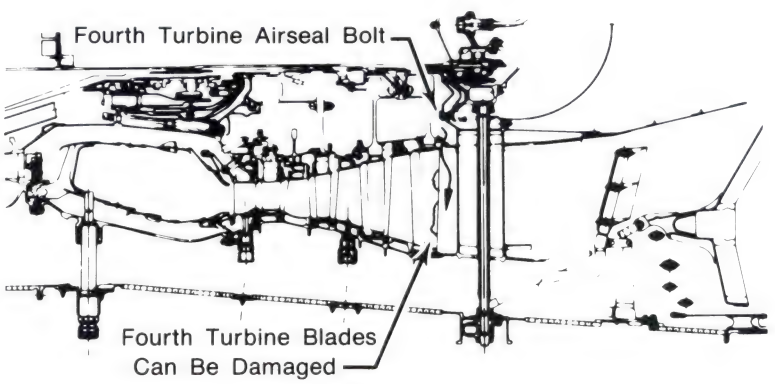
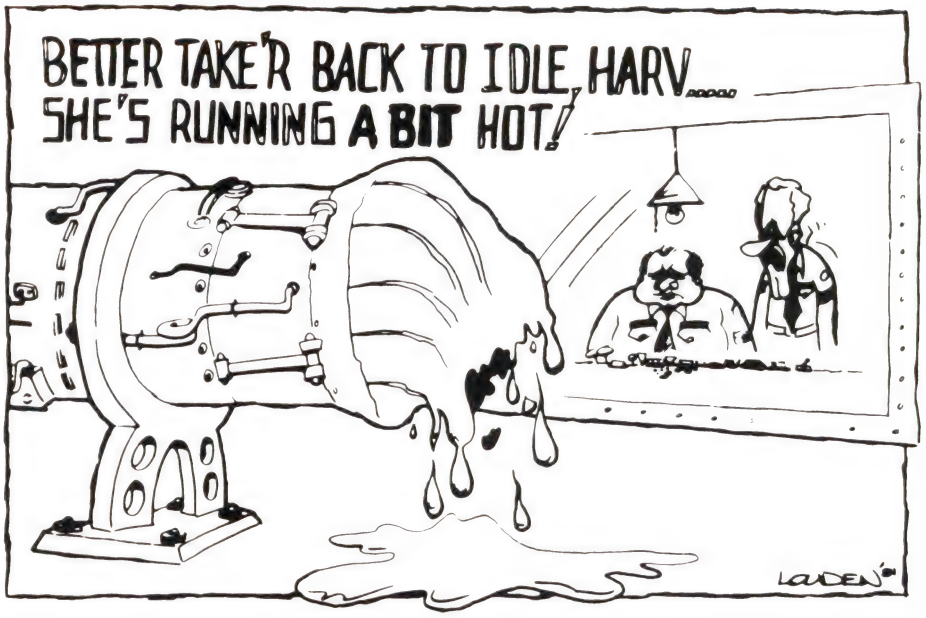


Figure VI-3. Fourth-Stage Turbine Airseal Bolts



NOZZLE BURNTHROUGH

Nozzle misassembly during maintenance continues to result in augmentor nozzle burnthrough and, in some cases, damage to aircraft structure.

Only careful and thorough assembly procedures, as called out in the T.O., will preclude future incidents. The nozzle works as designed as long as it's assembled correctly.

Make sure:

- The dogbone link attaching hardware is properly assembled and torqued.
- The balance-to-convergent flap hinge pins and tablocks are properly installed.
- The run-on torque check of the dogbone lock nut is complied with.

The omission of nozzle hardware during assembly can lead to serious incidents.

A videotape is available on this subject from your P&W representative.

THE MISSING DOGBONE

A fire onboard an aircraft in flight is a frightening thing. You can't just jump out and use a fire extinguisher at 30,000 feet. Let's look at an area where care in assembly can help prevent a fire.

One design feature of the F100 engine that allows it to use lightweight metals is the balanced augmentor nozzle system. By properly placing the

hinge points on the nozzle parts, internal and external pressures counterbalance each other. Less actuator muscle is then required to move the nozzle from one position to another. Figures A and B show the augmentor nozzle as it is positioned for non-augmented and augmentor operation.

When fuel is being burned in the augmentor to increase thrust, the exhaust gas temperature approaches 3,500°F. The temperature of the metal in the nozzle is maintained at or below 2,000°F by the cooling airflow shown in Figure VI-4. To ensure the cooling air gets where it is supposed to, all parts of the nozzle must be in place. If parts of the nozzle shift around, cooling air leaks and does not do its job. If cooling air leaks become too large, parts of the nozzle overheat and burn away.

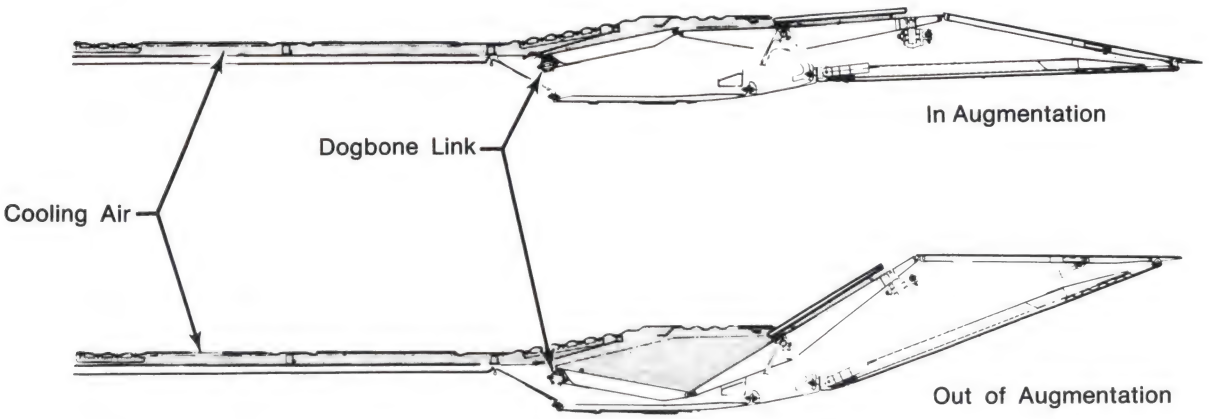


Figure VI-4. Cooling Airflow

One of the most common causes of this type failure is improper assembly of the parts shown in Figure VI-5. The flaps and seals that form the nozzle are interconnected by a series of links, commonly called dogbones because of their shape. Each end of the dogbone is attached to a flap with hardware consisting of a through bolt, washers, a uni-ball bearing, sleeve bushing and a locking nut. If all pieces are in place, the unit works; if something is missing, the system can wear or disengage.

In one incident, when the link broke, flaps shifted and cooling air leaked. Temperatures rose until the titanium nozzle parts started to burn. Investigators discovered that the uni-ball had been left out causing the dogbone link to fail and separate from the balance flap. This case had a relatively happy ending because the pilot was able to return the airplane safely and the only damage was to the nozzle.

Another part that is sometimes left out at assembly is the washer at either end of the retention bolt. These washers act as retainers to prevent disengagement of the bolt, nut and bushing combination from the balance flap. Again, watch the assembly procedures and be sure that all the parts are used in the right places. Failures can be prevented by going by the book!

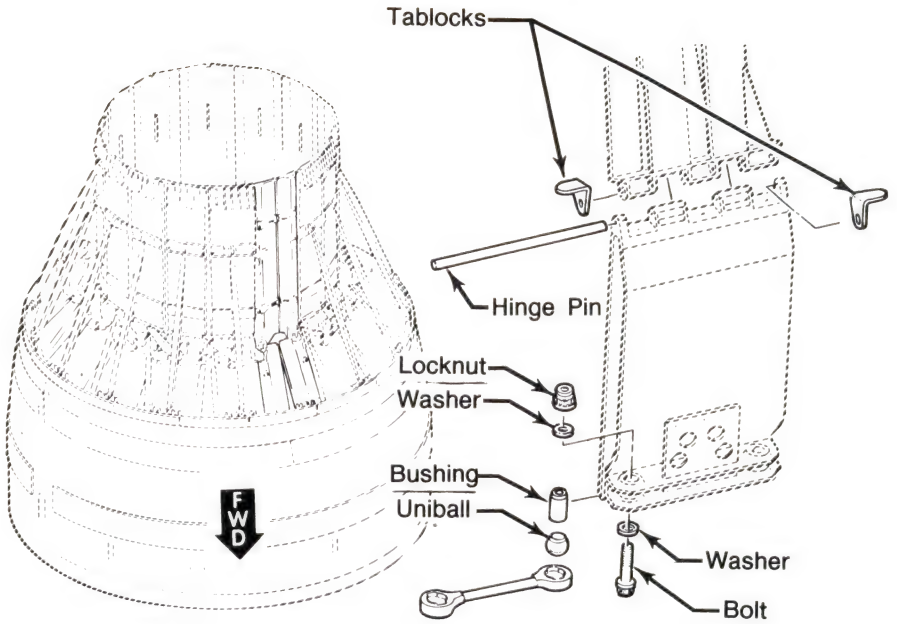


Figure VI-5. Proper Assembly of Afterburner

There has been a redesign of the dogbone link hardware, which reduces it to a two-piece assembly. Figure VI-6 shows the new bolt with its integral sleeve bushing and washer, and the nut with integral washer. This configuration is being delivered on new engines. Don't forget to ensure the uniball is in the dogbone.

There have been over 50 "burn-through" incidents associated with nozzle hardware misassembly. Be aware that hinge pin and tablock misinstallation is the next major cause after errors in dogbone hardware assembly.

Be especially thorough when assembling nozzle hardware. The omission of a washer worth pennies can result in damage valued in the millions, or worse yet, a serious mishap.

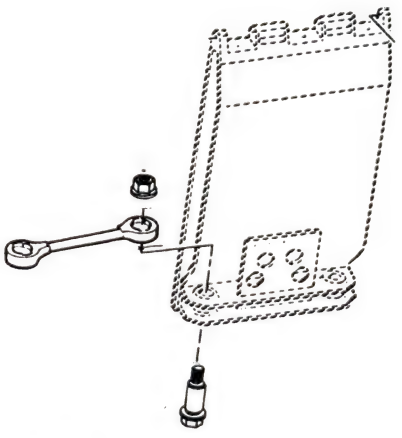


Figure VI-6. Two-Piece Dogbone Link Attaching Hardware

RCVV SYSTEM LOOSENESS

Mechanical looseness in the rear compressor variable vane system, especially between the RCVV bellcrank and its torque tube (Figure VI-7), can cause reduced engine performance. Let's review why looseness develops, why performance is degraded because of it and what can be done to prevent it.

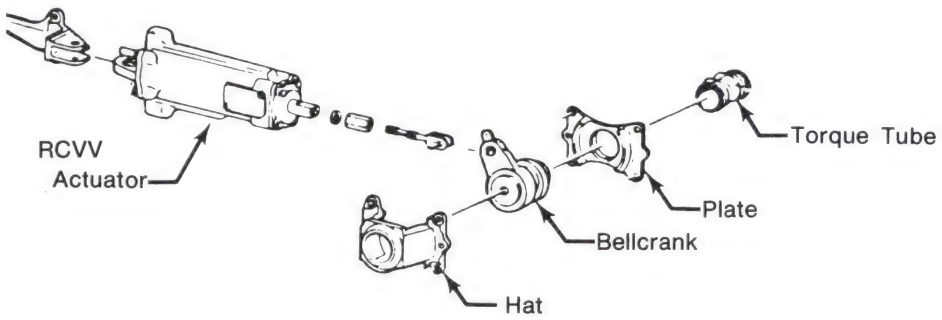


Figure VI-7. RCVV Actuation System External Linkage

The RCVV bellcrank converts the linear (straight line) motion of the RCVV actuating cylinder output shaft to rotational motion used internally by the RCVV linkage on the core module. The torque tube transfers this motion from the external bellcrank through the fan duct to the internal linkage which moves the RCVV's.

Current new and refurbished torque tube splines have a copper-nickel coating which creates a tight shear fit when inserted into the internal spline of the bellcrank. However, as engine cycles accumulate and the copper-nickel coating deteriorates, the titanium bellcrank splines begin to wear. Unequal thermal expansion between the core, external fan duct and RCVV-actuating parts causes misalignment between the torque tube and bellcrank splines. This misalignment increases the contact area loading in the spline.

Since the titanium bellcrank is softer than the steel torque tube, the bellcrank splines wear. As Figure VI-8 shows, this wear leaves a "footprint" in the bellcrank spline. A "backlash effect" then develops and accelerates the process.

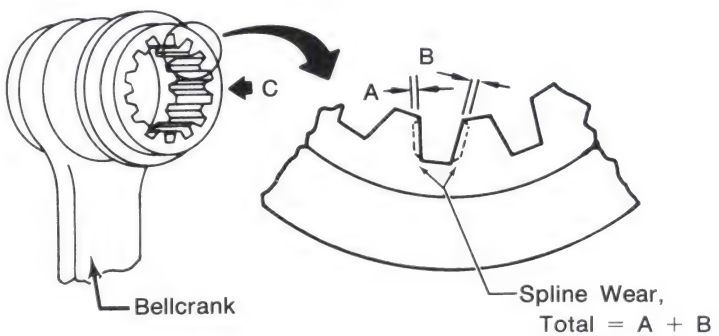
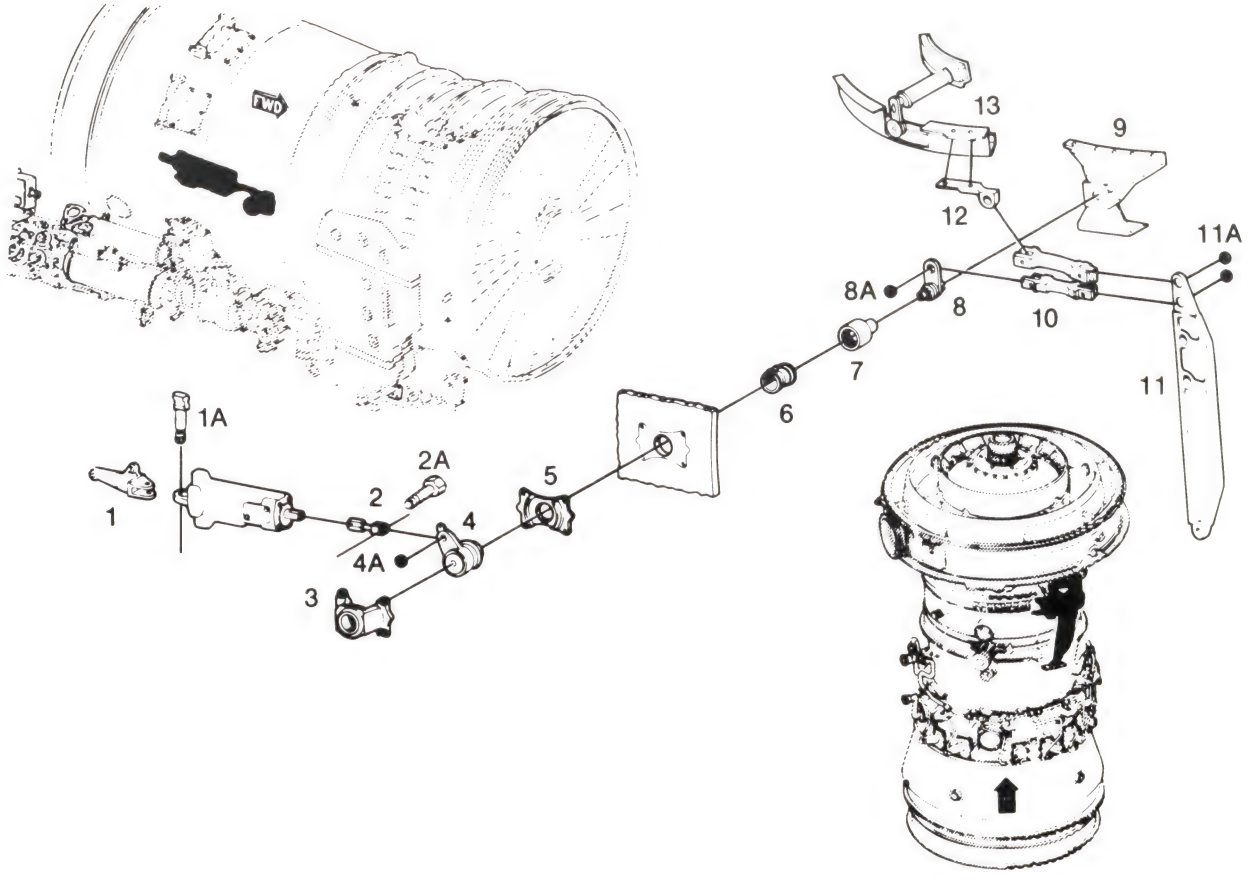


Figure VI-8. RCVV Ballcrank Spline Wear

Although wear between the bellcrank and its torque tube is the most common cause of RCVV system looseness, some looseness can develop between other system parts too. Figure VI-9 lists these parts and describes their wear locations. Regardless of the location of the wear, however, the result is the same — degraded engine performance. Let's see why.



	Part Name	Wear Location
1	Compressor Stator Cylinder Support	Boltholes
1A	Compressor Stator Cylinder Bolt	Shank
2	Rod End Clevis	Bolthole
2A	Machine Bolt	Shank/Threads
3	Compressor Stator Linkage Arm Bearing ("Hat")	Journal Contact Diameter
4	Right and Left Compressor Stator Linkage Arms ("Bell Cranks")	Journal Splines
4A	Self-Aligning Plain Bearing ("Uniball")	Uniball/Outer Race Interface
5	Compressor Stator Linkage Arm Bearing ("Plate")	Journal Contact Diameter

	Part Name	Wear Location
6	Compressor Stator Linkage Shaft ("Torque Tube")	Spline Coating (CuNi)
7	Compressor Stator Linkage Coupling	Journal Diameter
8	Compressor Stator Linkage Arm	Journal Diameter
8A	Self-Aligning Plain Bearing ("Uniball")	Uniball/Outer Race Interface
9	Rear Compressor Stator Linkage Arm Bracket ("Bow Tie Bracket")	Bushing Holes

	Part Name	Wear Location
10	Compressor Stator Rigid Connecting Link	Boltholes
11	Rear Compressor Stator Synchronizing Arm ("Pump Handle")	Sliding Contact Surface
11A	Self Aligning Plain Bearing ("Uniball")	Uniball/Outer Race Interface
12	Inlet Rear Compressor Stator Ring Bracket	Uniball Wear
13	Rear Compressor Inlet Stator Synchronizing Ring Assembly	Pin Holes/Pins Uniballs Channel

Figure VI-9. Additional RCVV System Wear Points

Looseness in the RCVV system linkage results in less movement of the variable vanes for a given input of RCVV actuator movement. In other words, the variable vanes are more cambered than they should be (Figure VI-10). This results in a less-efficient rear compressor. Higher EEC trims can compensate for the RCVV looseness and the resulting decrease in compressor efficiency. However, higher trim settings lead to less compressor and fan stall margin which may lead to increased A/B stalls. Stagnations will also increase as stall recoverability is decreased. Deceleration stalls or stall/stagnations, particularly those below intermediate, can be caused or enhanced by RCVV looseness. The looseness also increases the hysteresis in the system; thus the RCVVs remain more cambered during accelerations, and more axial during decelerations. This can drive the engine into the stall region.

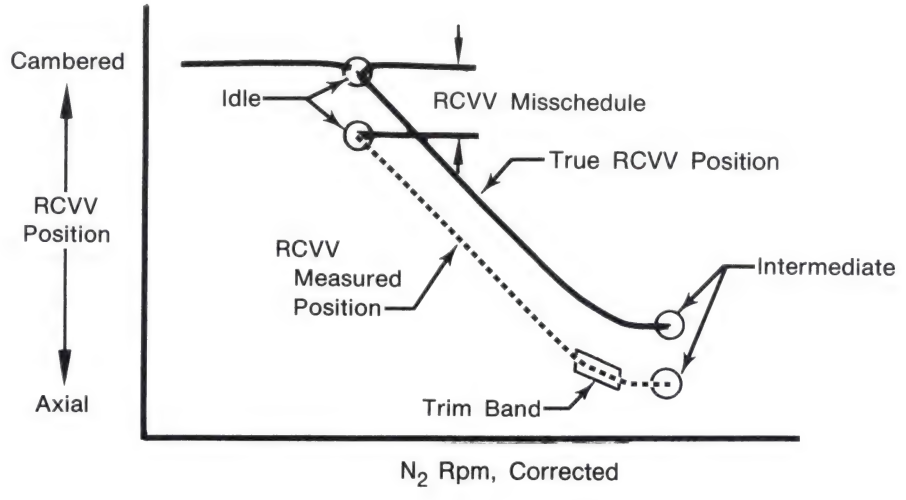


Figure VI-10. Effect of RCVV Looseness on Engine Trim

An important step in preventing RCVV system looseness is proper installation of torque tubes and bellcranks, and overall inspection of the system. Here are some tips:

- Visually inspect the torque tube for coating flaking, and bellcrank splines for wear (''footprints'') prior to installation.
- Ensure the sheared spline fit is maintained between the outer bellcrank arm, shaft and internal coupling.
- Preshear torque tubes to eliminate the requirement for excessive force during installation.
- Use the PWA 52791 pusher to install the torque tube; not an impact device (hammer).
- Check torque tube positioning carefully. It's been proven that torque tube misalignment can cause RCVV binding and grinding noise.
- Inform your P&W representative of all torque tubes received from supply which have insufficient coating to obtain proper sheared-spline fit. Also report installation difficulties caused by excessive coating.
- Replace bellcranks and torque tubes when bellcrank spline backlash exceeds the T.O. looseness limits.
- Be sure to inspect bellcrank arm-to-bearing support fit for excessive looseness.

Speaking of inspection, there are two opportunities to check for RCVV looseness outside of the JEIM shop. The first is during RCVV calibrations prior to trimming. The second is during the EPR trimming operation. In the case of the RCVV calibration opportunity, before most trim runs, an RCVV calibration is performed. This is done using a hydraulic pressure cart to actuate the RCVV cylinder. During the procedure, watch for the cylinder to "jump" backward when hydraulic pressure is applied. Also, watch for sideways uniball or bellcrank arm movement prior to arm rotation (Figure VI-11). These abnormal movements indicate looseness. In the case of the EPR (inlet temperature = 20°F) trimming inspection opportunity, an indication of RCVV looseness will be excessive N_2 rpm (Figure VI-12) (an uninstalled N_2 speed exceeding 12,950 rpm or an installed N_2 speed exceeding 92.7 percent point to RCVV looseness).

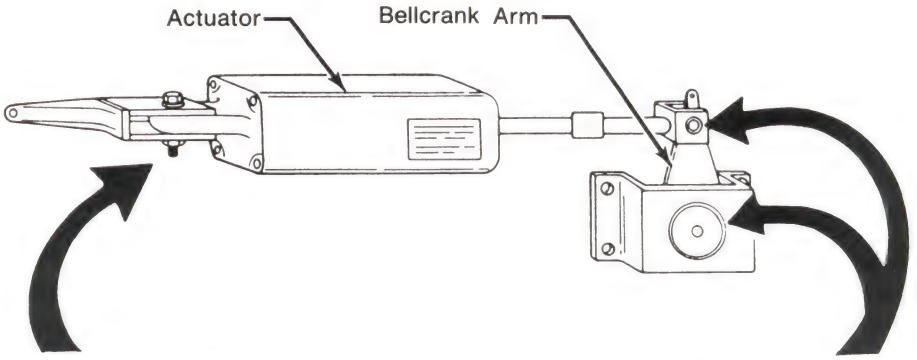

Actuator
Bellcrank Arm
During RCVV actuation watch for the actuator to "jump" back when hydraulic pressure is applied.
Watch for uniball or bellcrank arm movement sideways prior to arm rotation.

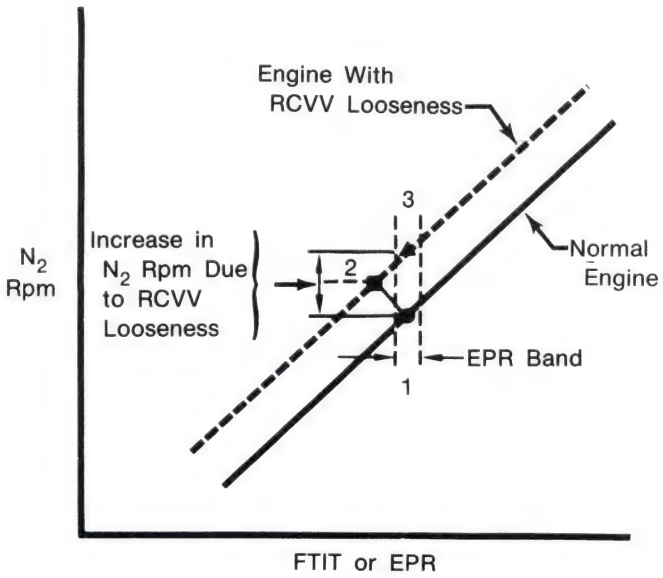
Figure VI-11. Inspection Points Which Can Reveal RCVV Looseness

We've talked a bit about how the RCVV system works, what causes the looseness, and how the looseness affects engine performance. Let's take a moment now to look at some of the things P&W and the USAF are doing to prevent performance losses due to RCVV part wear. To begin with, the depot has repairs for worn bellcrank arms, torque tubes and linkage arm bearings ("hats" and "plates"). The reworked hardware has a much longer life than the present bill-of-material parts.

Manual changes have been made which should help. One change requires a looseness check of RCVV bellcranks before each uninstalled trim. This check is done in the shop during an inspection prior to a test cell trim run. The trim T.O.'s have been revised; a thrust parameter check to prevent thrust loss due to RCVV looseness has been added.

It's very important that the RCVV system functions properly if the performance built into the F100 is to be maintained. Linkage wear, both internal and/or external, degrades this performance. In the near term, careful inspection of the system during calibration and trimming, followed by replacement of worn parts, is recommended. In the long term, modifications to the system and associated procedures have been

implemented which should reduce the wear that causes looseness. Proper installation of the parts is important. Be sure to refer to your T.O. when working on the RCVV system.



1. ● Normal Engine
2. ■ Engine with RCVV looseness
   a. N_2 Rpm will be higher than normal
   b. EPR will be low
3. ▲ After Retrim
   a. N_2 Rpm will be higher than normal
   b. EPR will be in normal band, but a higher than normal N_2 trim setting will be required to get it there.
   c. Reduced fan stall margin in ULHC will result

Figure VI-12. Effects of RCVV Looseness on EPR and N_2

New RCVV Bellcrank Arms

Production and depot overhauled engines are now being delivered with new improved (steel insert) RCVV bellcrank arms (PN's 4059318 and 4059313). You should also have them in spares stock.

The new configuration, Figure VI-13, is much more durable than the titanium arm (PN's 4023083 and 4027671).

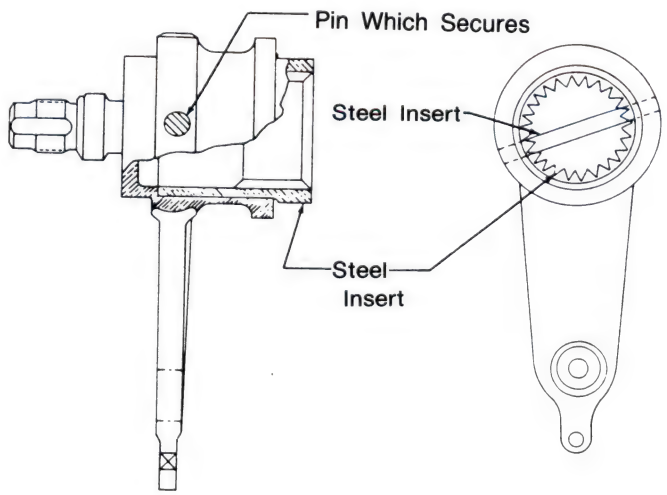


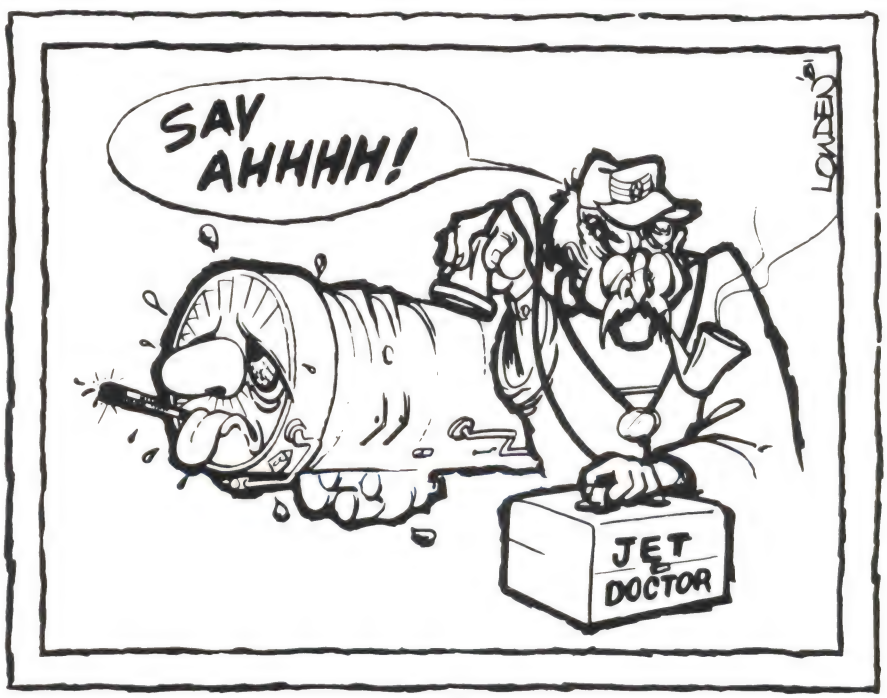
Figure VI-13. New RCVV Bellcrank Arms

Steel sleeve insert RCVV arms have been rejected for ID spline wear indications. Investigation of the subject arms found wear to be anti-gallant coating on the spline, but no wear to the parent material.

Please be aware that the new steel sleeve insert RCVV bellcrank arms may add wear to the spline anti-gallant coating without having parent metal damage or associated hysteresis problem. The new steel bellcrank should be carefully inspected for parent metal ID spline wear prior to a rejection decision.

AUDIBLE WARNINGS

In most commercial airliners and in many military aircraft, cockpit voice warnings are used to alert pilots of impending or existing problems. The F100 engine can emit audible warnings of a different nature, which can only be understood by the discerning ear of maintenance personnel.



An incident occurred when an unusual noise was heard by an alert crew chief while rotating a fan by hand. In addition to the sound of fan blade midspan shrouds "clanking" as he turned it, he also heard an unfamiliar rattle. It turned out to be a loose fan tie-rod nut rolling around between the disks. A possible disaster was averted.

A few years back, a test cell crew alerted a P&W representative to an unusual, low-pitched, oscillating hum at idle. It turned out to be a No. 4

bearing missing some cross rails and well on its way to failure. An immediate JOAP sample confirmed the problem (high iron). Another possible disaster was averted by a well-tuned ear.

So, listen closely to the language of your machinery. It's talking to you each time it's operated, and only you, the maintenance technician, knows when the engine is saying, "I have a problem."

USING THE KOLLMORGAN BORESCOPE

When assessing damage through a Kollmorgan borescope, it is important to use AP adapters provided in the kit.

Each adapter has a different shape to it, and an arrow with the word "Fan" imprinted on it. By using the appropriate adapter, the borescope will be inserted perpendicular to the engine centerline. This is vital to accurate damage measurement, which is based on "depth of field" when focusing on the damaged part.

If the scope is inserted perpendicular to the outer case (without the appropriate AP adapter), the tip of the scope will be either too close or too far away from the target, which will mislead you in assessing the extent of the damage, because the focal length is incorrect. Again, damage measurements are based upon accurate focal length.

So, be aware that failure to use the necessary adapter can cause you to erroneously measure gaspath distress.

EXCESSIVE FTIT SPREAD

There have been numerous incidents of F100 engines being rejected, and some multiple rejections, for excessive max to min FTIT spread. As yet, a specific cause has not been defined.

Some areas that have been "field-tried and tested" are provided for your information. The following parts can contribute to, or be a cause of, high spread: fuel nozzles, combustion chamber, first-stage turbine vanes, FTIT probes, diffuser case and diffuser splitter.

Several procedures to correct high spread have been employed at various TAC bases. As previously stated, there are multiple reasons for high spread. Hence there are multiple remedies for high spread. When an engine is rejected from the test cell for high spread, preliminary troubleshooting should be used (FTIT probes and harness checks) prior to engine removal. Once the engine has been returned to the shop and disassembled at the "G" flange, areas to inspect are:

Fuel Nozzles (swirl and non-swirl) — This is possibly the leading candidate for high spread. Field testing at various TAC bases suggests that favorable results can be obtained by arranging the 16 fuel nozzles

so that no more than a maximum of five PPH between nozzles exists. This is accomplished by starting at the 12 o'clock position with the lowest flow, and installing nozzles of increasing flow in a clockwise and counterclockwise direction, noting not to install an adjacent nozzle with a flow greater than five PPH from the previously installed one (Figure VI-14). For example, if the 12 o'clock nozzles were 710 PPH, the 6 o'clock nozzles should be no greater than 745 PPH.

Although this technique to improve margin has not been issued as a change to the T.O., it does not violate it. Field experience indicates this technique is usually successful.

Example: (Maximum Flow Arrangement)

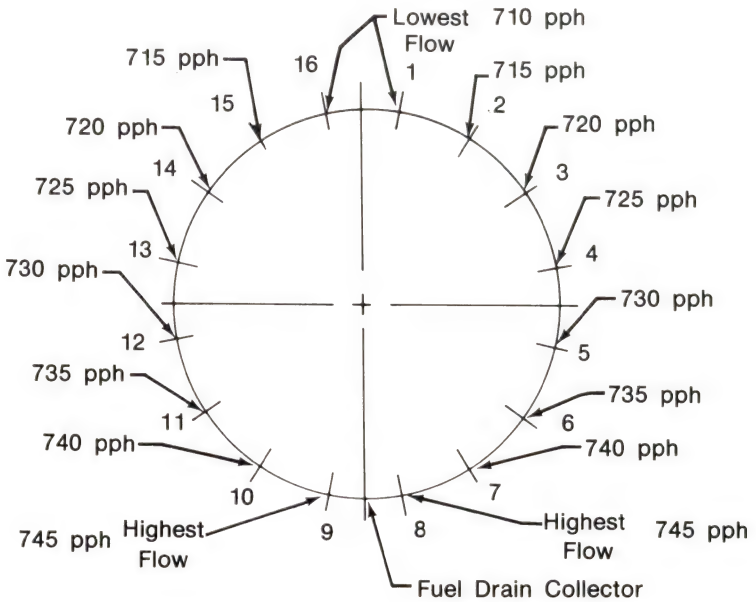


Figure VI-14. Maximum to Minimum Flow Rates

Combustion chamber — Inspect for any defects that could disrupt airflow. Pay particular attention to the cowl area (outer front of can). This area is critical to airflow and must be free of any irregularities.

Diffuser case fairing assembly (commonly called the splitter) — Any abnormalities or deviations from bill-of-material, such as bulges, dents or excessive weld bead, can cause a disruption in airflow and possibly affect spread.

Diffuser case — Although the least likely candidate for spread problems, this too can affect spread if there are any defects that would lend themselves to disrupting airflow.

IGNITER PLUGS

There have been instances of engines failing to start because both main igniters failed. This is unfortunate because statistics tell us that the scheduled system checks, if done correctly, should weed out the single igniter failures and, for the most part, eliminate double failures (Figure VI-15).

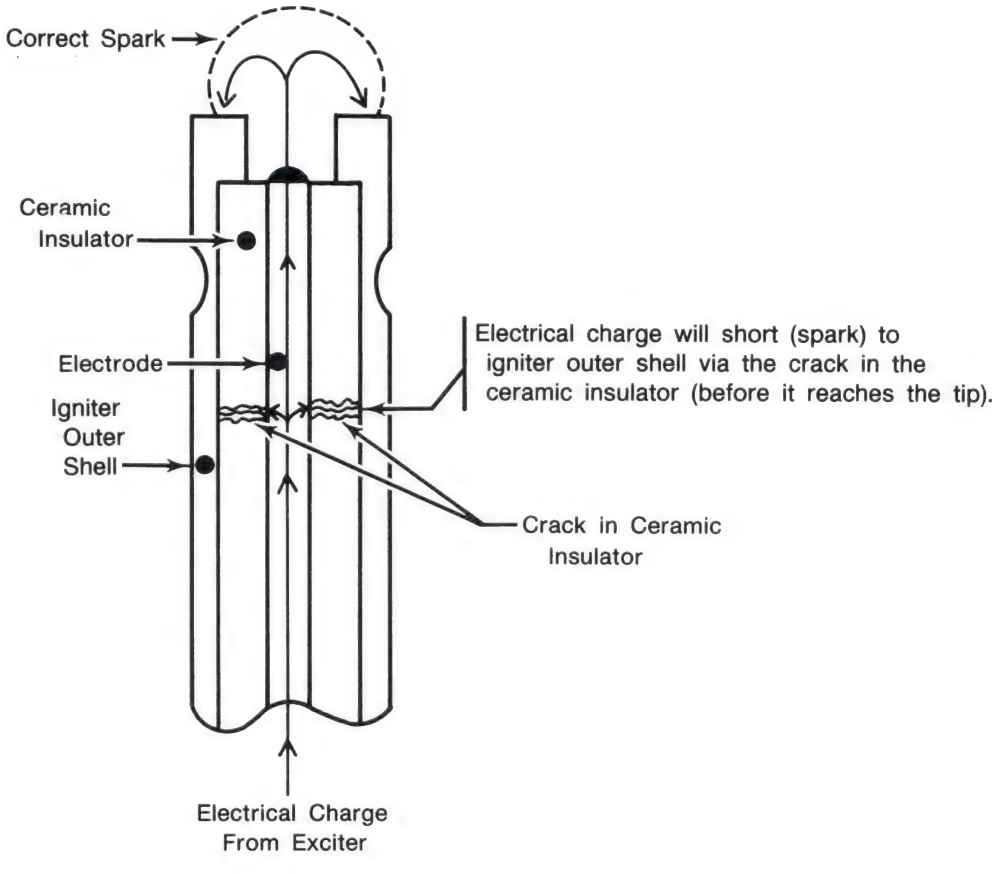

Correct Spark
Ceramic Insulator
Electrode
Igniter Outer Shell
Electrical charge will short (spark) to igniter outer shell via the crack in the ceramic insulator (before it reaches the tip).
Crack in Ceramic Insulator
Electrical Charge From Exciter

Figure VI-15. Igniter Plug Tip

For the inspection, your T.O. describes two methods of detecting faulty igniters. The first is the static visual check. It's designed to reveal such things as a cracked ceramic, gap erosion beyond limits, and unusual wear or physical damage. The second method, which is the surest way of detecting bad igniters, is the functional check. Although the T.O. gives the procedures for performing this check, it's very important for you to be able to visually tell the difference between a good and bad igniter plug firing.

Listening for spark "snaps" will not identify a cracked ceramic insulator. By using the PWA 50025 Ignition Tester per tech data, you can see the spark to ensure proper sparking at the plug tip. This will identify single igniter failures and negate double failures that constitute a safety hazard (unable to airstart).

STUCK FTIT PROBES

Occasionally an F100 fan turbine inlet temperature thermocouple probe will swell and get stuck in the third-stage turbine vane. When this happens be extremely careful how you remove it because if the probe breaks, the tip will remain in the vane.

A common cause of tip breakage results from trying to twist the stuck probe to free it. Do not twist it. If the tip does break off in the vane, it will require extensive follow-on maintenance to remove it. Proper use of the PWA 55191 puller (Figure VI-16) will alleviate tip breakage in most cases.

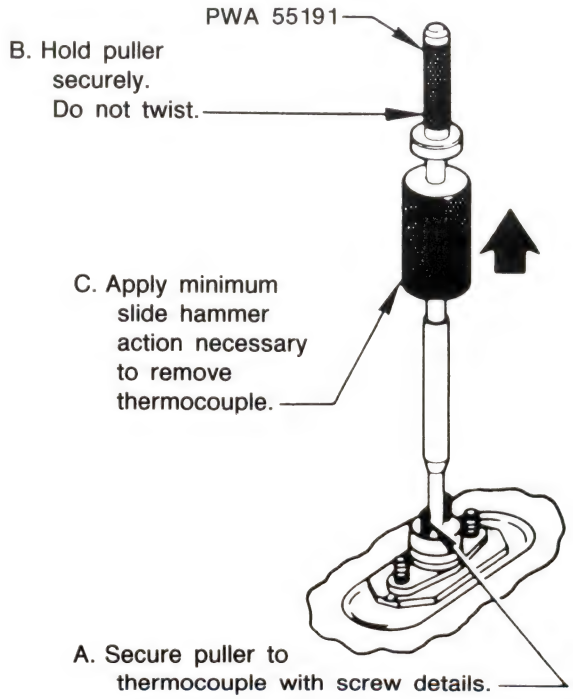

PWA 55191
B. Hold puller securely. Do not twist.
C. Apply minimum slide hammer action necessary to remove thermocouple.
A. Secure puller to thermocouple with screw details.

Figure VI-16. Thermocouple Removal Using PWA 55191 Puller

There have also been occurrences of tip breakage when properly using the puller per tech data. This prompted design of the Probe Element Extraction Kit (PWA 55190), which will ease removing broken tips from installed turbine vanes.

Note: A video tape on the use of the kit is available from your P&W representative.

CHAFING (NO. 5 BEARING SCAVENGE TUBE/STEPPER AND SOLENOID SPECIAL-PURPOSE CABLE)

There have been incidents of oil leakage caused by chafing action between the No. 5 bearing scavenge tube and the cable. Contact occurs between the cable and the scavenge tube. Several other known instances of chafe or contact have been reported. Investigation has revealed the need for an additional clamp at this location, which will be incorporated in the T.O. in the near future.

It is recommended that this area be checked when work is being performed, or the area is accessible, to ensure adequate clearance. Repositioning the clamp/cable is recommended to achieve clearance.

This is a chafing problem which could result in a serious inflight mishap if not caught in time.

CORE REJECTION (SEALANT ON AIRFOILS MISINTERPRETED AS FOD)

A core was recently rejected at a field location for 12th- and 13th-stage compressor damage (FOD). Subsequent disassembly of the core revealed a quantity of PWA 553 blade root sealant on the airfoils in question. No airfoil damage was noted.

Assembly procedures stress the removal of any excess sealant from the airfoils, however, seeing this condition (sealant) at any location is not a cause for rejection. Note: this sealant is used only on stages 9 through 13.

If you have a question regarding crack indications, contact your P&W representative.

MAINTENANCE HAZARD ANALYSIS

The Maintenance Hazard Analysis program was formed to identify and correct tech order procedures that can result in injury to personnel (warnings, cautions, etc.), be misinterpreted by the user or lead to unsafe system operation.

You're undoubtedly aware of the narrow-banded limits of fighter operations. It has to be "in the band" — too low, it won't perform and may lose the fight; too high, it may "come apart." This program works to make sure it's "in the band."

Particular attention is being paid to Work Package T.O.s. Typographical and procedural rewrite errors are being quickly identified and corrected through the proper USAF channels. The channel you use within USAF to correct T.O.s is AFTO Form 22.

Since you use the T.O.s on a daily basis, you can help get needed changes/corrections by informing your local P&W representative and initiating an AFTO Form 22. Pratt & Whitney's engineering staff and technical writers can then begin researching problems along with USAF authorities.

F100 ENGINE WARRANTY PROGRAM

There are four major warranties associated with the F100:

Supply warranty — warrants to repair or replace any part found to be defective in material or workmanship within 240 days of first installation in an aircraft when installed within one year after acceptance date.

Expanded engine warranty — warrants to repair or replace any engine, module or accessory found to be unserviceable to the limits of the technical orders within the first 200 hours total operating time or two years from acceptance date, whichever occurs first.

High pressure turbine warranty — warrants to repair or replace high pressure turbines found to be unserviceable to the limits of the technical orders for durability reasons within the time period indicated on the AFTO Form 95.

Fan disk warranty — warrants fan disks against any disk failure caused by a manufacturing flaw for a period of 3,000 equivalent TAC cycles or 10 years after original acceptance date.

To determine warranty eligibility, follow these steps:

1. Look at the engine or module data plate (for ease of identification only warranty engine/modules have a "Warranted — see AFTO 95" statement engraved on the data plate).
2. Check the AFTO 95.
3. Check engine records to determine current times, cycles and other information necessary to make the correct warranty determination.
4. Consult a Pratt & Whitney field representative.

Warranted time-traced accessories and modules are covered by the expanded warranty regardless of which engine they are installed on.

To initiate a warranty claim, write a service report. Refer to T.O. 00-35D-54 for SR reporting procedures.

OIL TANK SIGHT GAUGE READABILITY

Oil tank sight gauges are being found discolored. This discoloration is on the wall of the tank behind the lens as well as on the sight lens. It can make the oil service level hard to check. Because an improperly serviced engine can cause an engine inflight shutdown, extreme care must be taken to ensure proper servicing.

Procedures have been incorporated into the technical orders for inspecting and cleaning the sight gauge. These procedures are to hand-wipe the lens and wall behind the lens with a clean cloth moistened with PD-680, Type II petroleum solvent, or the equivalent (Figure VI-17).

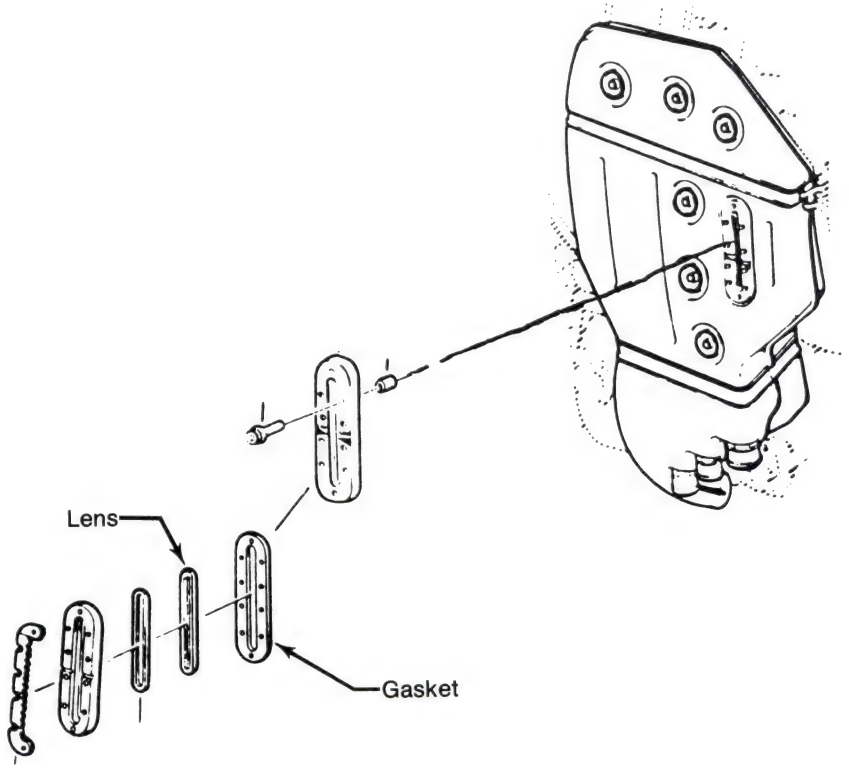


Figure VI-17. Oil Tank Sight Gauge Lens and Wall Behind the Lens

Always refer to tech data to ensure compliance with current procedures. Inspections are done during the aircraft post-flight inspection on the flight line and during oil tank inspection in the JEIM shop. In order to alleviate unscheduled engine removals, give this inspection special attention during JEIM visits.

Keep in mind that the lens is glass. It is fragile and often broken when pried from the gasket/tank. Use care during disassembly.

FAN KNIFE-EDGE SEALS

Fan knife-edge seals (Figure VI-18) and/or blade retainers must be protected with the proper devices when they are exposed during maintenance. They are critically important to the structural integrity of the fan. Also, be sure to comply with the "cotton swab" inspection according to the T.O. This will identify edge flaws which could propagate into a crack and fracture.

Although these fan seals are not removed at JEIM, there are several others that are exposed during maintenance in the shop. Be sure to protect them from damage.

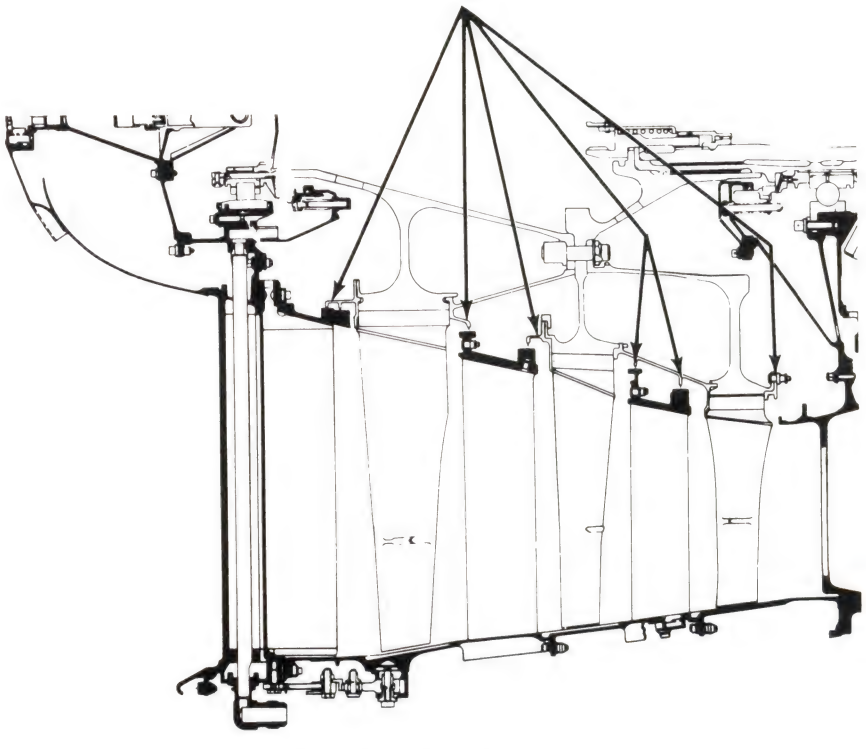


Figure VI-18. Fan Airseals/Blade Retainers

Tools of Our Trade

Section VIII

TECHNICAL ORDER

The Technical Order, or T.O. as it is more commonly known, is a technician's most important tool. It is the only guide for proper maintenance procedures. The following list will help you familiarize yourself with each propulsion system T.O. and its purpose. The 2J-F100-26 (-1 through -11) T.O.'s break the engine down into modules, components and procedures.

T.O. Number	Title
2J-F100-26-1	Introduction and general information about the F100-PW-100 engine
-2	On-condition maintenance instructions (special inspections)
-3	Support equipment (AGE) and a numerical list of -100 tooling
-4	Engine accessories and rigging procedures
-5	Engine disassembly, repair and assembly
-6	Inlet fan module disassembly, repair and assembly
-7	Core module disassembly, repair and assembly
-8	Rear compressor drive turbine disassembly, repair and assembly
-9	Fan-drive turbine module disassembly, repair and assembly
-10	Augmentor duct and nozzle module disassembly, repair and assembly
-11	Gearbox module intermediate repair

The numerical list of organization level (installed engine) T.O.'s follow.

T.O. Number	Title
1F-15A-2-00FR-00-1	Fault Reporting
1F-15A-2-05JG-20-1	Engine and JFS Operation
1F-15A-2-71FI-00-1	Fault Isolation
1F-15A-2-71GS-00-1	General System
1F-15A-2-71JG-00-1	Job Guide — General
1F-15A-2-71JG-01-1	Engine Removal and Installation
1F-15A-2-71JG-02-1	Engine Trim — Open Field and Hush House
1F-15A-2-71JG-03-1	Engine Trim — Industrial Acoustics Company Noise Suppressor System
1F-15A-2-71JG-04-1	Engine Trim — Jetway Corporation Noise Suppressor System
1F-15A-2-71JG-05-1	Engine Trim — Environmental Elements Corporation Noise Suppressor System
1F-15A-2-71JG-20-1	Engine Mounts
1F-15A-2-71JG-50-1	Engine Electrical Harness
1F-15A-2-71JG-60-1	Air Intakes
1F-15A-2-71JG-60-2	Air Intakes
1F-15A-2-71JG-60-3	Air Intakes
1F-15A-2-71JG-70-1	Engine Drains
1F-15A-2-71SD-00-1	Schematic Diagram — PowerPlant System
1F-15A-2-72JG-20-1	Air Inlet
1F-15A-2-72JG-60-1	Accessory Drive
1F-15A-2-73JG-10-1	Engine Fuel System — Distribution
1F-15A-2-73JG-20-1	Engine Fuel System — Controlling
1F-15A-2-73JG-30-1	Engine Fuel System — Indicating
1F-15A-2-74JG-10-1	Engine Ignition System — Electrical Power Supply
1F-15A-2-74JG-20-1	Engine Ignition System — Distribution

T.O. Number	Title
1F-15A-2-75JG-10-1	Engine Air System — Engine Anti-icing
1F-15A-2-75JG-30-1	Engine Air System — Compressor
1F-15A-2-76JG-10-1	Engine Control System — Power Control
1F-15A-2-76JG-10-2	Engine Control System — Power Control
1F-15A-2-77JG-10-1	Engine Indicating System — Power
1F-15A-2-77JG-20-1	Engine Indicating System — Temperature
1F-15A-2-77JG-30-1	Engine Indicating System — Analyzers
1F-15A-2-78JG-10-1	Engine Exhaust System — Nozzle
1F-15A-2-78JG-10-2	Engine Exhaust System — Nozzle
1F-15A-2-79JG-10-1	Engine Oil System — Storage
1F-15A-2-79JG-20-1	Engine Oil System — Distribution
1F-15A-2-79JG-30-1	Engine Oil System — Indicating
1F-15A-2-80FI-00-1	Fault Isolation — Engine Starting System
1F-15A-2-80GS-00-1	General System — Engine Starting System
1F-15A-2-80JG-00-1	Engine Starting System — General
1F-15A-2-80JG-10-1	Engine Starting System — Hydraulic
1F-15A-2-80JG-11-1	Engine Starting System — Jet Fuel Starter
1F-15A-2-80JG-11-2	Engine Starting System — Jet Fuel Starter
1F-15A-2-80JG-12-1	Engine Starting System — Central Gearbox
1F-15A-2-80JG-12-2	Engine Starting System — Control
1F-15A-2-80JG-12-3	Engine Starting System — Central Gearbox
1F-15A-2-80SD-00-1	Schematic Diagram — Engine Starting System
1F-15A-2-83JG-00-1	Accessory Gearbox System — General
1F-15A-2-83JG-10-1	Accessory Gearbox System — Driveshaft
1F-15A-2-83JG-20-1	Accessory Gearbox System — Airframe Mounted Accessory Drive
1F-15A-2-83JG-20-2	Accessory Gearbox System — Airframe Mounted Accessory Drive
1F-15A-4-5	Illustrated Parts Breakdown — Fuel System, Engine and Related Systems — F-15A and F-15B
1F-15A-4-6	Illustrated Parts Breakdown — Aerospace Ground Equipment — F-15A and F-15B
1F-15A-4-7	Illustrated Parts Breakdown — Index — F-15A and F-15B
1F-15A-6	Inspection and Maintenance Requirements Manual — F-15A and F-15B

IGNITION TEST SET (PWA 50025)

The ignition test set (Figure VII-1) verifies proper operation of the engine ignition system. The PWA 50025 test set:

- Provides power to simulate voltage normally supplied by the engine stator generator for ignition (variable).
- Verifies proper spark rate and stored energy of ignition exciters (by individual exciter).
- Verifies ignition harness/circuitry integrity.
- Facilitates visual/functional igniter firing.

Be extra careful when operating the tester. It generates enough electrical energy to be considered hazardous to the operator if proper procedures and T.O. warnings are not followed.

Applicable T.O.: 33D4-5-515-1; Power requirements: 115 VAC/50-400 Hz

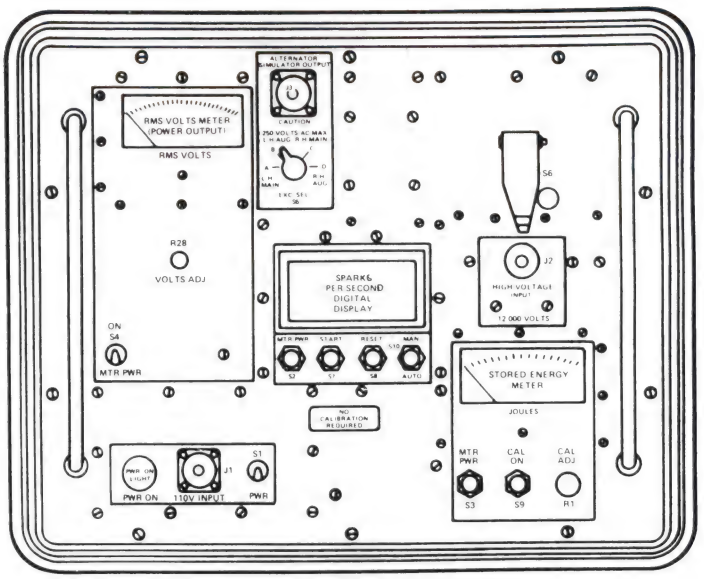


Figure VII-1. Ignition Test Set (PWA 50025)

MACH NUMBER SIMULATOR (PWA 50037)

During maintenance, the Mach number simulator (Figure VII-2) provides all inputs to the engine normally supplied by the aircraft. The simulator provides a variable octal Mn signal, normally provided by the AIC and discrete inputs such as IAR, EEC trimout (EEC on/off) and rocket fire (now used for PLAP retard).

Applicable T.O.: 33D4-6-518-1; Power requirements: 115 VAC/50-400 Hz

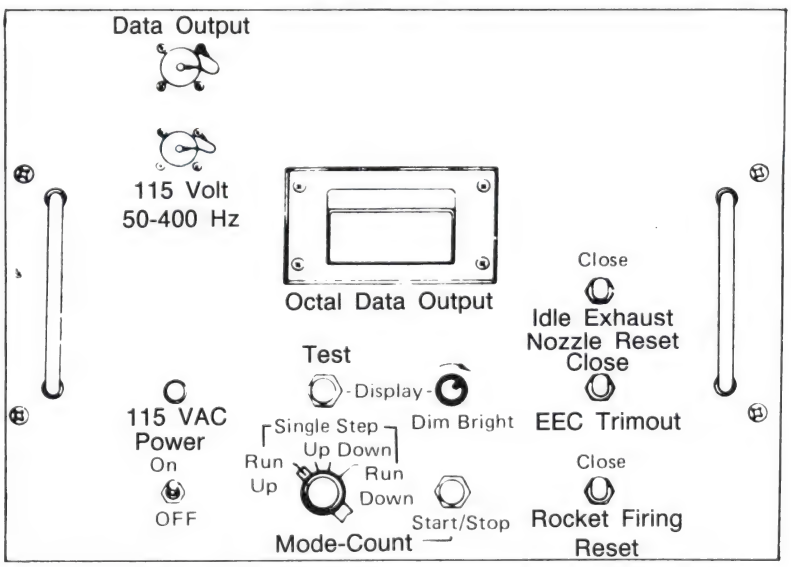


Figure VII-2. Mach Number Simulator (PWA 50037)

ENGINE TRIM BOX (PWA 50081)

The engine trim box (Figure VII-3) is used to monitor critical parameters during engine trim. The trim box:

- Monitors critical operating parameters (rpm, temperatures positions and pressures).
- Corrects parameters to standard day.
- Indicates control system faults (Levels 2 and 3).
- Generates false T_t2 for EPR trim.
- Checks FTIT spread.

It is very important that this unit be properly calibrated, otherwise it could result in engine mistrim. This, of course, will cause degraded engine performance, and serious inflight incidents such as stalls and stagnations. If there is any reason to suspect improper ETB operation, consult PMEL.

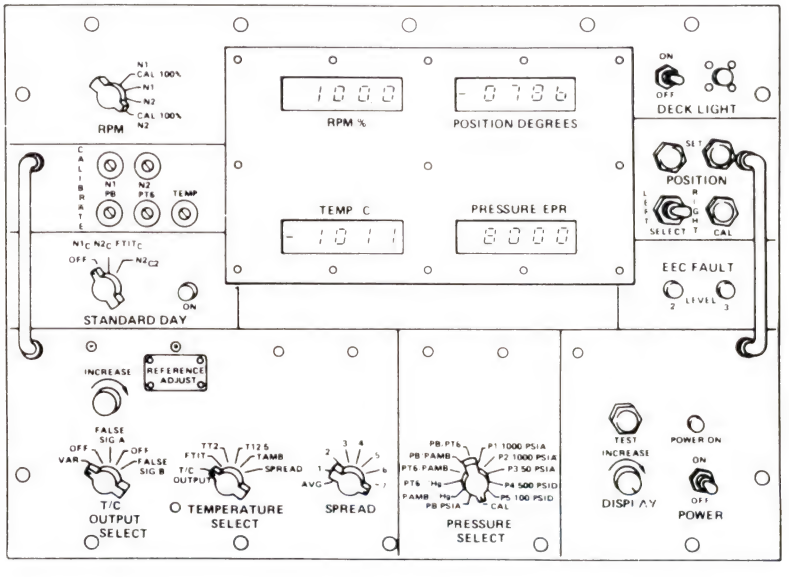


Figure VII-3. Engine Trim Box (PWA 50081)

Applicable T.O.: 33D4-6-556-1; Power requirements: 115 VAC/50-400 Hz

SUPERVISORY CONTROL SYSTEM TEST SET (PWA 50105)

The SCS tester (Figure VII-4) checks and troubleshoots the F100's electronic control system.

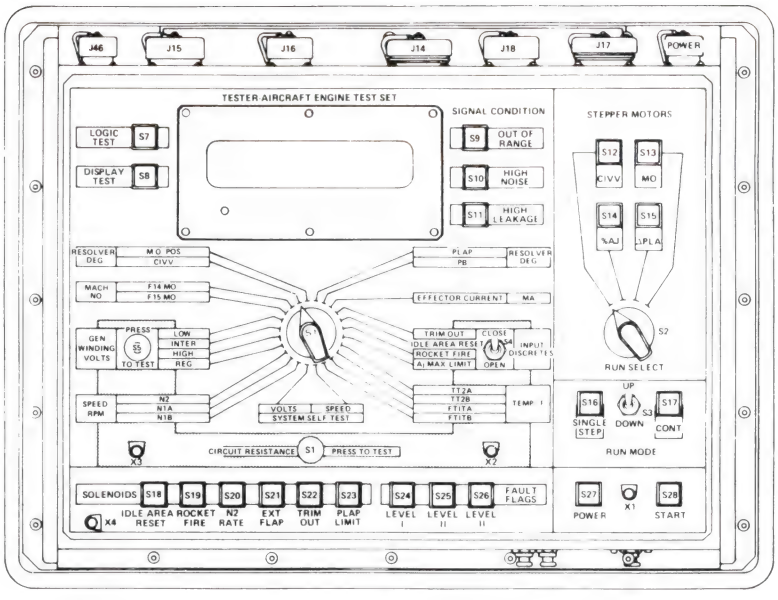


Figure VII-4. Supervisory Control System Test Set (PWA 50105)

The tester performs two levels of tests: static (engine off) and dynamic (engine running) troubleshooting. When the SCS tester is connected to the engine, it becomes a manually controlled EEC monitoring all electrical control system functions.

The SCS test set:

- Self-tests to verify proper tester operation.
- Checks discrete inputs (cockpit command verification).
- Provides readouts for critical engine operating parameters (rpm, temperatures).
- Verifies proper stepper motor and resolver operation.
- Drives stepper motors while verifying degrees of rotational movement.
- Monitors milliamperage required to drive stepper motors.
- Verifies control system solenoid functions (IAR, PLAP retard, trim out, etc.).
- Verifies voltage output and resistance check of engine stator generator windings.

Treat this unit with care. It is your most valuable troubleshooting tool. Driving a vehicle over SCS cables can cost more than $5,000 to repair.

Applicable T.O.: 33D4-6-521-1; Power requirements: 115 VAC/400 Hz

PWA 51932 HEATER

An "assembly technique" complaint has surfaced concerning temperature testing when using the PWA 51932 heater.

The PWA 51932 heater is an immersion blower type unit with an air intake temperature adjustment. The temperature is adjusted by opening and

closing the air intake. It would be difficult to provide a more accurate metal-to-metal thermocouple probe contact because of the nature of the heater and its hot air environment. Pratt & Whitney recommends using a standard hand-held pyrometer.

When using this heater, a standard pyrometer is required. Recently, an Alnor pyrometer was approved by the Air Force. The part number is PN 4000A, NSN 6685-00-080-0186. This pyrometer is a compact, hand-held portable unit especially designed for industrial use.

PWA 25672 HEATER CONTROL

The PWA 25672 heater control unit uses a panel-mounted module (FENWAL thermocouple-sensing temperature controller) which mounts in the front panel of the control unit.

Replacement controller modules (FENWAL PN 55-003140-308) may be smaller than those used originally since the manufacturer no longer makes a larger size. An adapter plate is required to adapt the smaller module to the oversized panel cutout. This plate may be locally fabricated from sheet aluminum or steel, or it may be ordered through normal supply channels. The FENWAL (manufacturer's code 73168) Adapter Plate is listed under vendor PN 06-232-029-005, PWA PN 25672, Detail 13.

PWA 50308 WRENCH

Along with its many uses, this wrench is used to torque and untorque the No. 1 bearing inner retaining nut and the hub cover nut on the first-stage fan disc and hub.

The wrench has compound torque gauges which read in both pound-foot and pound-inch torque values. Pound-foot values are not listed in F100 tech data.

There have been several incidents where the No. 1 bearing inner retaining nut has been over overtorqued, resulting in nut and hub damage. A TCTO has been issued to prevent this from occurring. It is important to remember that only the pound-inch scale should be used when operating the PWA 50308 wrench.

ENHANCED HORIZONTAL MAINTENANCE CAPABILITY (JEIM)

Current tech data require that the core module be removed and placed in a vertical maintenance stand to remove and replace the No. 2 bearing or the 2-3 bearing-area carbon seals.

To facilitate R/R of the pinion gear (IAW TCTO 2J-F100-718), new tooling was designed to allow horizontal teardown of the No. 2-3 bearing area without having to remove the core or fan-drive turbine.

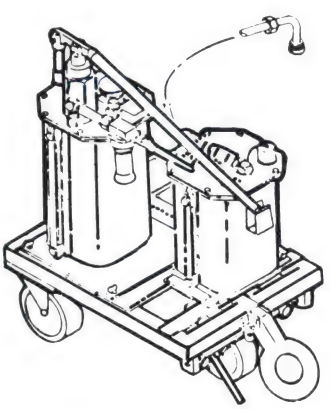
The new tooling and procedures will be available in the near future. They are expected to reduce the time required to perform maintenance in the No. 2-3 bearing area by approximately 200 MMH.

TANK AND PUMP UNIT

The tank and pump unit (Figure VII-5) is used to service the engine with lubricating oil for normal maintenance purposes. The 3-gallon capacity oil supply tank is hand-operated to provide a 20 psig service pressure and is equipped with a resettable meter, dispensing and return hoses and an overflow tank, all mounted on a movable dolly. The tank and pump unit may either be towed behind a vehicle or hand-towed. The dispensing and return hoses are a minimum of 6 feet in length and are equipped with nozzles and sockets for attachment to a mating fitting on the aircraft. The pump provides a delivery rate of 2 gallons per minute at 70°F.

The unit is also used to service the constant-speed drive portion of the integrated drive generator. A flexible drain line is used in conjunction with the tank and pump unit to direct the flow of oil from the overfill bleed boss to a suitable container. A return flow of oil is the indication of a fully serviced system.

PN: PMU-29/E per MIL-T-38266
NSN: 4930-00-620-2406
Applicable T.O.s: 35-1-226WC-1
35-1-3
37A-12-11-1



Tank and Pump Unit

Figure VII-5. Tank and Pump Unit

PACER WRENCH PROGRAM

The F100 engine support equipment review group is called Pacer Wrench. This group was established to resolve problems in supporting and maintaining F100 tooling. Problems usually fall into one of four areas: design/quality deficiencies, spares provisioning, tech data deficiencies and TA authorization.

This is your program, and in order for it to be effective your participation is needed. Please let the USAF and P&W know about problems by submitting an SR,IAW T.O. 00-35D-54 or AF Form 1000 (USAF Suggestion Program). Your participation will help expedite tooling improvements.

ENGINE COMPLEX AGE INFORMATION

The following is a list of the most often used F100 complex AGE and the T.O.'s that apply.

PWA PART #	PART NAME	NSN	T.O. NUMBER
50045	Cart-hydraulic pressure	4920-00-502-2660	35D29-3-6-1
50047	Test set-pneumatic, A/C engine components	4920-00-502-2284	35D29-8-2-1
50096	Test equipment-compressor vane	4920-01-035-6342	33D4-6-617-1
50132	Maint. kit-A/C engine, KMU-472/E (short fibrescope)	6650-01-075-6642	32A2-18-1
50025	Test set-ignition, A/E 24T-116	4920-00-439-5525	33D4-6-515-1
50037	Test set-Mn simulator	4920-00-210-6315	33D4-6-518-1
50083	Fuel control group-A/C engine, EAU-11/E (remote trimmer)	4920-01-040-5949	33D4-6-519-1
50105	Test set-SCS	4920-00-216-9141	33D4-6-521-1 (also -4)
50079	Adapter kit-A/C engine, KMU-454/E (M37 adapter kit)	4920-00-508-9135	33D4-6-522-1 (also -4)
50080	Adapter kit-test stand, KMU-453/E (M37 adapter kit)	4920-00-505-8807	33D4-6-523-1 (also -4)
50319	Maint. kit-A/C engine, KMU-449/E (rigid borescope)	6650-00-782-4619	33D4-6-524-1
50081	Test set-A/C engine, A/E 24T-141 (engine trim box)	4920-01-020-8041	33D4-6-556-1 (also -4)
50207	Mechanical throttle system (M37)	4920-01-059-5107	33D4-6-610-1

Personnel Safety

Section VIII

DANGER AREAS

There are many noises, high temperature and radioactive danger areas to be aware of when working on an engine. The information in this section is designed to protect maintenance personnel and anyone in the work area from injury.

Key points to remember are:

- Intake suction, even at idle, can pull hats off and suck loose articles from pockets, etc. It will ingest you if you are not aware of the danger areas in Figure VIII-1.
- During a run, and for some time after shut down, the engine cases and plumbing lines can badly burn you.
- The PTO shaft is spinning at high speed. Loose clothing, fingers and long hair are vulnerable in this area.
- The JFS gases are not of great velocity, but they are very hot (Figure VIII-2).
- In the unlikely event of a turbine disk separation on the ground, be aware that it has the energy of a small bomb. Don't stand in the turbine wheel plane of rotation, which is marked by a red band on the airframe (engine and JFS).
- Antennas, such as those used for communication or radar, emit high energy levels that can be dangerous to the human body. Be aware of antenna locations and make sure they are deactivated when working near them (Figure VIII-3).
- The sound level produced by even an idling engine can damage your hearing. Always wear approved ear protection (Figure VIII-4).

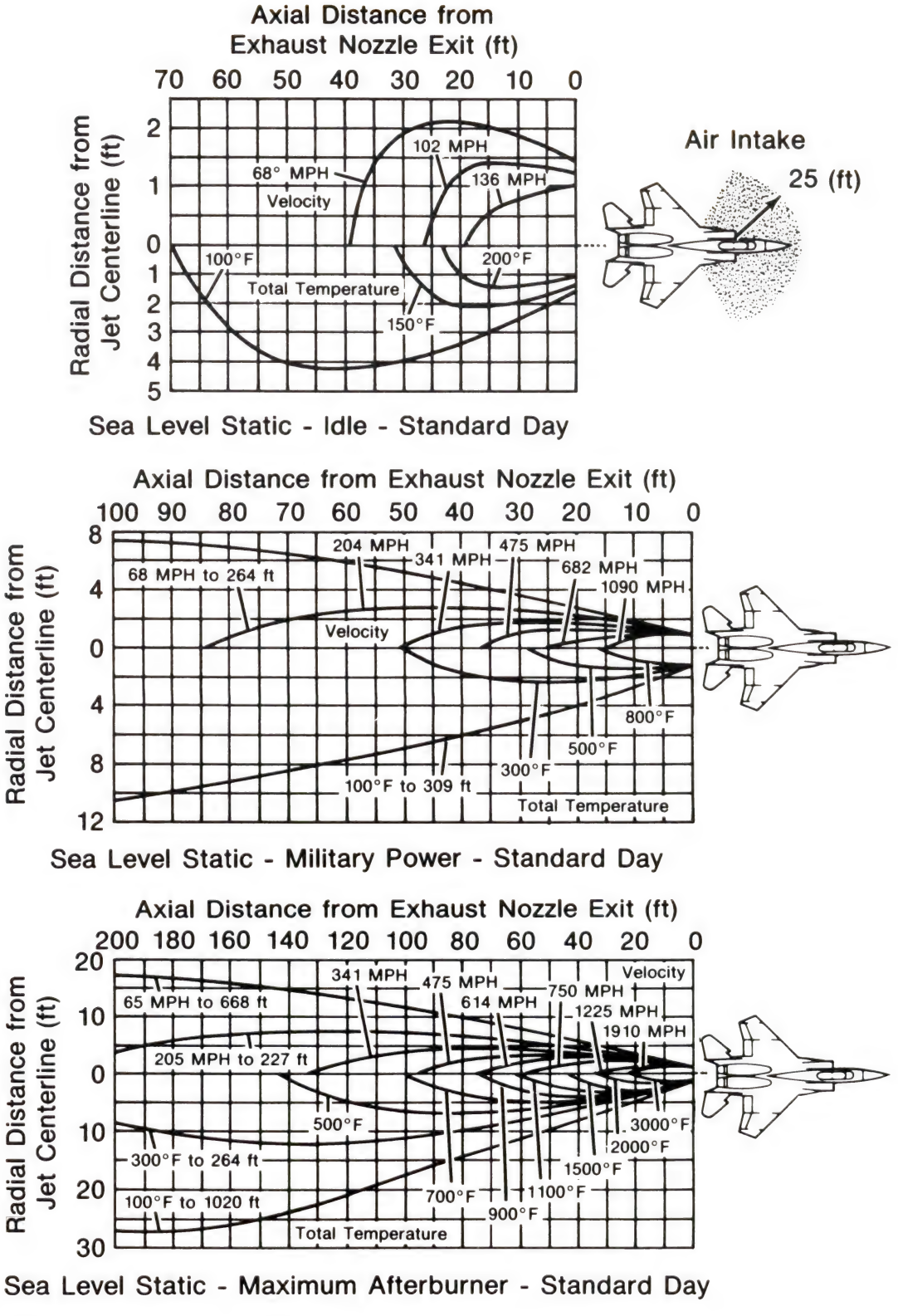


Figure VIII-1. Engine Operation Danger Areas

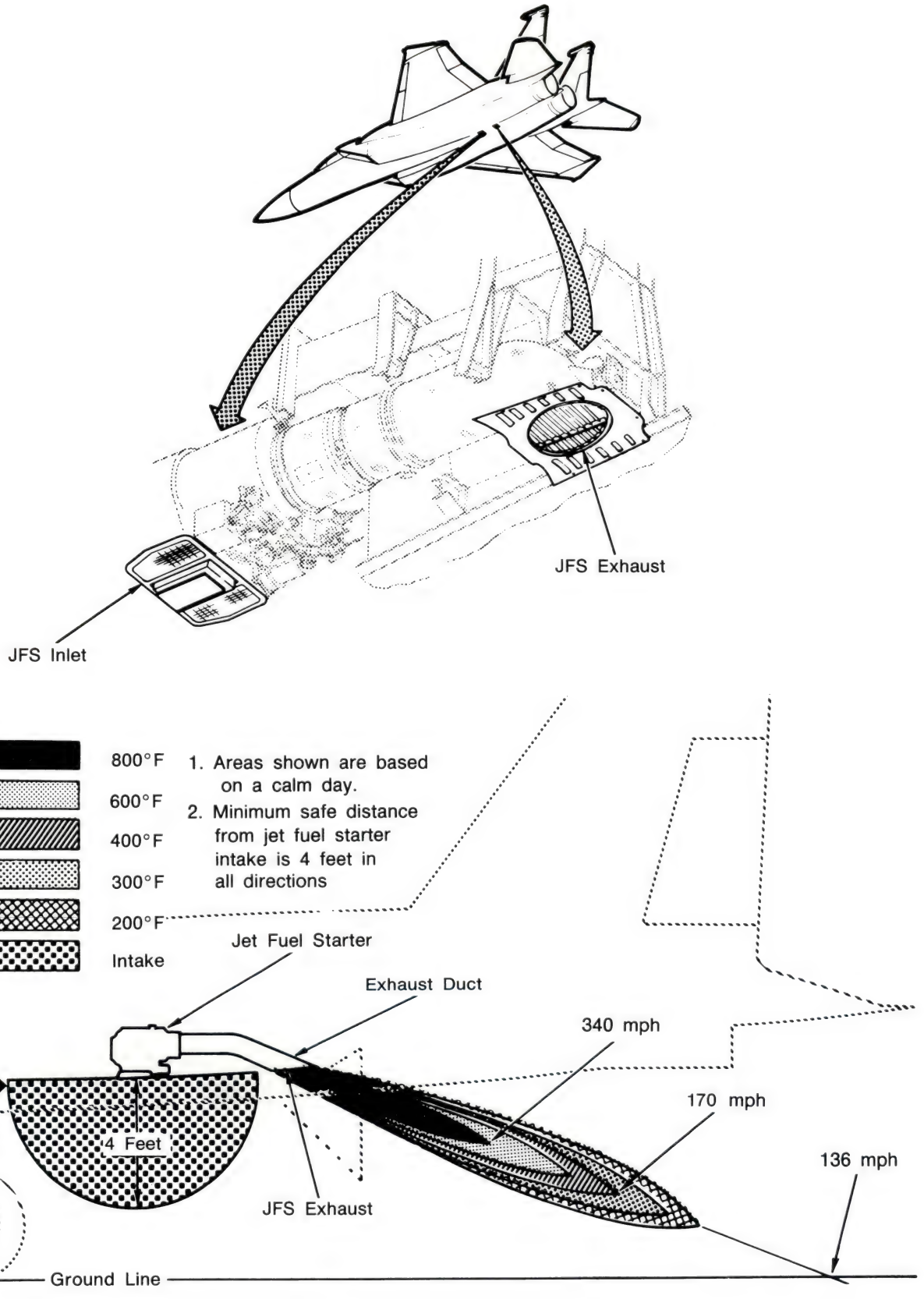
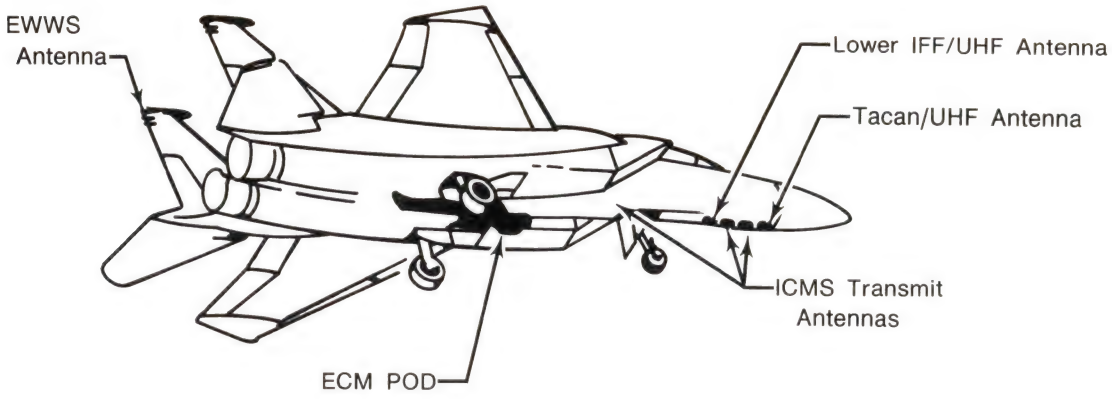
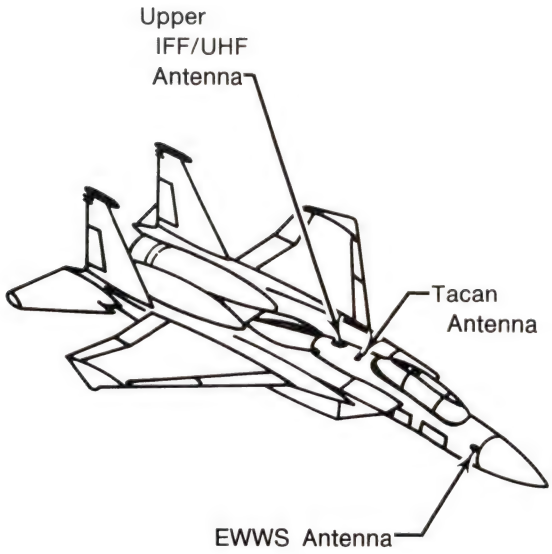
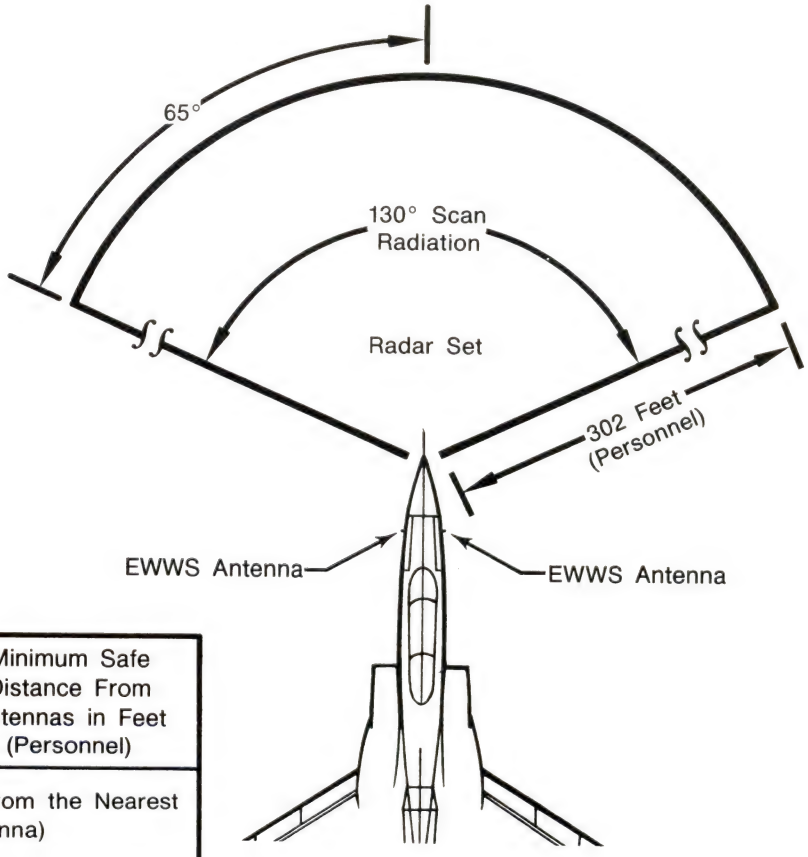


Figure VIII-2. Jet Fuel Starter Danger Areas



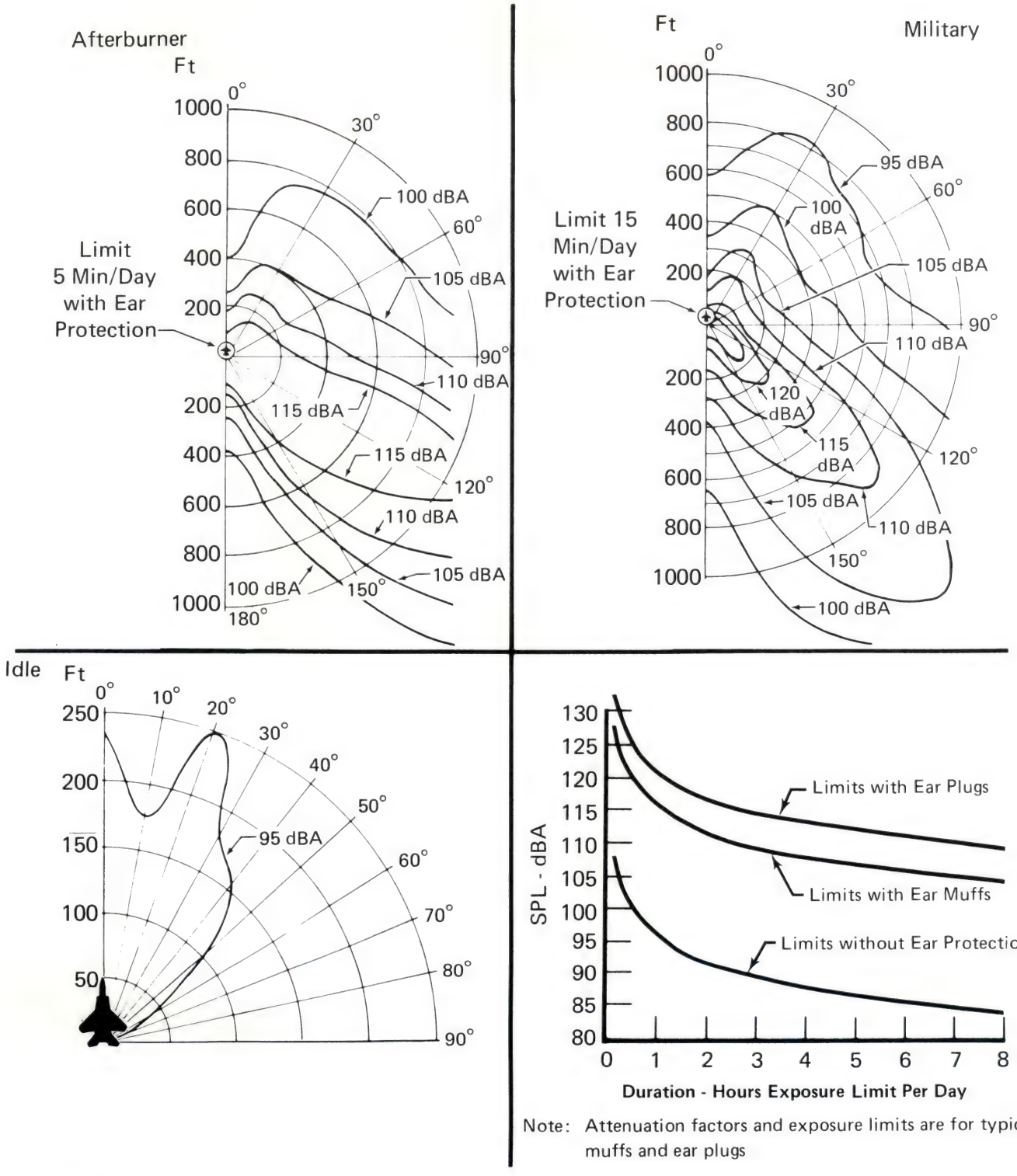




Operating Transmitters	Minimum Safe Distance From Antennas in Feet (Personnel)
Forward Internal Countermeasures Transmitting Antennas (2) (ICMS)	5 (From the Nearest Antenna)
Aft/Internal Countermeasures Transmitting Antenna (ICMS)	3
Upper Tacan Antenna Lower Tacan/UHF Antenna	8
Upper and Lower IFF/UHF Antennas	2
Radar	302
FWWS	10
POD AN/ALQ-119(V)-12	6

* All distances shown are based on maximum power output at which transmitter can be normally operated.

Figure VIII-3. Radiation Danger Areas



Note: Attenuation factors and exposure limits are for typical muffs and ear plugs

Note: Noise levels are symmetrical and may be altered by surrounding obstacles

Figure VIII-4. Hazardous Noise Level Areas

Glossary

Section IX

ACRONYMS AND ABBREVIATIONS

A_j	Exhaust nozzle area
A/C	Aircraft
AB	Afterburner (augmentor)
AC	Alternating current
Aft	Rearward
AGE	Aerospace ground equipment
AIC	Air inlet controller
AMAD	Aircraft-mounted accessory drive
amp	Ampere
AP	Access port
AUG	Augmentor (afterburner)
Auto	Automatic
Aux	Auxilary
Avg	Average
B/M	Bill of material
BPO	Basic post-flight inspection
$C_2/C_{2.5}$	Represents standard day correction factors and is used to correct the observed data. This provides a standard for comparison of engines operated under different conditions P_{amb} and OAT.
CCW	Counterclockwise
CENC	Convergent exhaust nozzle control
CG	Center of gravity
CGB	Central gearbox
CIP	Component Improvement Program
CIVV	Compressor inlet variable vane
CND	Could not duplicate
CSD	Constant speed drive
CW	Clockwise
Deg	Degree (temp or position)
ECS	Environmental control system
EEC	Engine electronic control
EHR	Events history recorder
Emerg	Emergency
ENP	Exhaust nozzle position
ENPT	Exhaust nozzle position transmitter
EPR	Engine pressure ratio
ETB	Engine trim box
Exch	Exchanger
F/B	Feedback
FOD	Foreign object damage
FS	Fuselage station (normally followed by a station number)
FTIT	Fan turbine inlet temperature
FWD	Forward
F100	F-15's powerplant (F100-PW-100)

G/B	Gearbox
GEN	Generator
GPD	Pratt & Whitney's Government Products Division
Gpm	Gallons per minute
HSD	Hamilton Standard Division
HUD	Head-up display
HYD	Hydraulic
Hz	Hertz (cycles or frequency)
I/C Box	Interconnecting box
S/O	Shutoff
SCS	Supervisory control system (tester)
SDU	Standard day unit
Sec	Second(s)
Seg	Segment (refers to Segments of AB)
SR	Service Report
T_{amb}	Ambient temperature
T_t2	Engine fan inlet total temperature
$T_t2.5$	Fan exit temperature
TA	Table of allowances
TC	Thermocouple
TCTO	Time Compliance Technical Order
T.O.	Technical Order
UC	Unified control (also known as unified fuel control (UFC))
UCR	Unconfirmed component removal
ULHC	Upper left-hand corner (flight envelope)
V_{max}	Maximum velocity
VAC	Volts, alternating current
VDC	Volts, direct current
W_f	Fuel flow
W_fGG	Gas generator (core) fuel flow
W_{ft}	Total fuel flow
WP	Work package
lb	Pound
qt	Quart
ft	Feet; foot

Symbols

Δ	Differential
ΔP	Differential pressure
θ	Theta (standard day temperature correction factor)
$\sqrt{\theta}$	Square root of theta
$\approx$	Approximately, at or near
$>$	Greater than
$<$	Less than

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